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Exam Part I

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Banks

1

Learning Objectives

After completing this reading you should be able to:

- Identify the major risks faced by a bank.
- Distinguish between economic capital and regulatory capital.
- Explain how deposit insurance gives rise to a moral hazard problem.
- Describe investment banking financing arrangements including private placement, public offering, best efforts, firm commitment, and Dutch auction approaches.
- Describe the potential conflicts of interest among commercial banking, securities services, and investment banking divisions of a bank and recommend solutions to the conflict of interest problems.
- Describe the distinctions between the "banking book" and the "trading book" of a bank.
- Explain the originate-to-distribute model of a bank and discuss its benefits and drawbacks.

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The word "bank" originates from the Italian word "banco." This is a desk or bench, covered by a green tablecloth, that was used several hundred years ago by Florentine bankers. The traditional role of banks has been to take deposits and make loans. The interest charged on the loans is greater than the interest paid on deposits. The difference between the two has to cover administrative costs and loan losses (i.e., losses when borrowers fail to make the agreed payments of interest and principal), while providing a satisfactory return on equity.

Today, most large banks engage in both commercial and investment banking. Commercial banking involves, among other things, the deposit-taking and lending activities we have just mentioned. Investment banking is concerned with assisting companies in raising debt and equity, and providing advice on mergers and acquisitions, major corporate restructurings, and other corporate finance decisions. Large banks are also often involved in securities trading (e.g., by providing brokerage services).

Commercial banking can be classified as *retail banking* or *wholesale banking*. Retail banking, as its name implies, involves taking relatively small deposits from private individuals or small businesses and making relatively small loans to them. Wholesale banking involves the provision of banking services to medium and large corporate clients, fund managers, and other financial institutions. Both loans and deposits are much larger in wholesale banking than in retail banking. Sometimes banks fund their lending by borrowing in financial markets themselves.

Typically the spread between the cost of funds and the lending rate is smaller for wholesale banking than for retail banking. However, this tends to be offset by lower costs. (When a certain dollar amount of wholesale lending is compared to the same dollar amount of retail lending, the expected loan losses and administrative costs are usually much less.) Banks that are heavily involved in wholesale banking and may fund their lending by borrowing in financial markets are referred to as *money center banks*.

This chapter will review how commercial and investment banking have evolved in the United States over the last hundred years. It will take a first look at the way the banks are regulated, the nature of the risks facing the banks, and the key role of capital in providing a cushion against losses.

COMMERCIAL BANKING

Commercial banking in virtually all countries has been subject to a great deal of regulation. This is because most national governments consider it important that individuals and companies have confidence in the banking system. Among the issues addressed by regulation is the capital that banks must keep, the activities they are allowed to engage in, deposit insurance, and the extent to which mergers and foreign ownership are allowed. The nature of bank regulation during the twentieth century has influenced the structure of commercial banking in different countries. To illustrate this, we consider the case of the United States.

The United States is unusual in that it has a large number of banks (5,809 in 2014). This leads to a relatively complicated payment system compared with those of other countries with fewer banks. There are a few large money center banks such as Citigroup and JPMorgan Chase. There are several hundred regional banks that engage in a mixture of wholesale and retail banking, and several thousand community banks that specialize in retail banking.

Table 1-1 summarizes the size distribution of banks in the United States in 1984 and 2014. The number of banks declined by over 50% between the two dates. In 2014, there were fewer small community banks and more large banks than in 1984. Although there were only 91 banks (1.6% of the total) with assets of $10 billion or more in 2014, they accounted for over 80% of the assets in the U.S. banking system.

The structure of banking in the United States is largely a result of regulatory restrictions on interstate banking. At the beginning of the twentieth century, most U.S. banks had a single branch from which they served customers. During the early part of the twentieth century, many of these banks expanded by opening more branches in order to serve their customers better. This ran into opposition from two quarters. First, small banks that still had only a single branch were concerned that they would lose market share. Second, large money center banks were concerned that the multibranch banks would be able to offer check-clearing and other payment services and erode the profits that they themselves made from offering these services. As a result, there was pressure to control the extent

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TABLE 1-1 Bank Concentration in the United States in 1984 and 2014

	1984			
Size (Assets)	**Number**	**Percent of Total**	**Assets ($ billions)**	**Percent of Total**
Under $100 million	12,044	83.2	404.2	16.1
$100 million to $1 billion	2,161	14.9	513.9	20.5
$1 billion to $10 billion	254	1.7	725.9	28.9
Over $10 billion	24	0.2	864.8	34.5
Total	**14,483**		**2,508.9**	
	2014			
Size (Assets)	**Number**	**Percent of Total**	**Assets ($ billions)**	**Percent of Total**
Under $100 million	1,770	30.5	104.6	0.8
$100 million to $1 billion	3,496	60.2	1,051.2	7.6
$1 billion to $10 billion	452	7.8	1,207.5	8.7
Over $10 billion	91	1.6	11,491.5	82.9
Total	**5,809**		**13,854.7**	

Source: FDIC Quarterly Banking Profile, www.fdic.gov.

to which community banks could expand. Several states passed laws restricting the ability of banks to open more than one branch within a state.

The McFadden Act was passed in 1927 and amended in 1933. This act had the effect of restricting all banks from opening branches in more than one state. This restriction applied to nationally chartered as well as to state-chartered banks. One way of getting round the McFadden Act was to establish a *multibank holding company*. This is a company that acquires more than one bank as a subsidiary. By 1956, there were 47 multibank holding companies. This led to the Douglas Amendment to the Bank Holding Company Act. This did not allow a multibank holding company to acquire a bank in a state that prohibited out-of-state acquisitions. However, acquisitions prior to 1956 were grandfathered (that is, multibank holding companies did not have to dispose of acquisitions made prior to 1956).

Banks are creative in finding ways around regulations—particularly when it is profitable for them to do so. After 1956, one approach was to form a one-bank holding company. This is a holding company with just one bank as a subsidiary and a number of nonbank subsidiaries in different states from the bank. The nonbank subsidiaries offered financial services such as consumer finance, data processing, and leasing and were able to create a presence for the bank in other states.

The 1970 Bank Holding Companies Act restricted the activities of one-bank holding companies. They were only allowed to engage in activities that were closely related to banking, and acquisitions by them were subject to approval by the Federal Reserve. They had to divest themselves of acquisitions that did not conform to the act.

After 1970, the interstate banking restrictions started to disappear. Individual states passed laws allowing banks from other states to enter and acquire local banks. (Maine was the first to do so in 1978.) Some states allowed free entry of other banks. Some allowed banks from other states to enter only if there were reciprocal agreements. (This means that state A allowed banks from state B to enter only if state B allowed banks from state A to do so.)

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In some cases, groups of states developed regional banking pacts that allowed interstate banking.

In 1994, the U.S. Congress passed the Riegel-Neal Interstate Banking and Branching Efficiency Act. This Act led to full interstate banking becoming a reality. It permitted bank holding companies to acquire branches in other states. It invalidated state laws that allowed interstate banking on a reciprocal or regional basis. Starting in 1997, bank holding companies were allowed to convert out-of-state subsidiary banks into branches of a single bank. Many people argued that this type of consolidation was necessary to enable U.S. banks to be large enough to compete internationally. The Riegel-Neal Act prepared the way for a wave of consolidation in the U.S. banking system (for example, the acquisition by JPMorgan of banks formerly named Chemical, Chase, Bear Stearns, and Washington Mutual).

As a result of the credit crisis which started in 2007 and led to a number of bank failures, the Dodd-Frank Wall Street Reform and Consumer Protection Act was signed into law by President Obama on July 21, 2010. This created a host of new agencies designed to streamline the regulatory process in the United States. An important provision of Dodd-Frank is what is known as the Volcker rule which prevents proprietary trading by deposit-taking institutions. Banks can trade in order to satisfy the needs of their clients and trade to hedge their positions, but they cannot trade to take speculative positions. There are many other provisions of Dodd-Frank. Banks in other countries are implementing rules that are somewhat similar to, but not exactly the same as, Dodd-Frank. There is a concern that, in the global banking environment of the 21st century, U.S. banks may find themselves at a competitive disadvantage if U.S. regulations are more restrictive than those in other countries.

THE CAPITAL REQUIREMENTS OF A SMALL COMMERCIAL BANK

To illustrate the role of capital in banking, we consider a hypothetical small community bank named Deposits and Loans Corporation (DLC). DLC is primarily engaged in the traditional banking activities of taking deposits and making loans. A summary balance sheet for DLC at the end of 2015 is shown in Table 1-2 and a summary income statement for 2015 is shown in Table 1-3.

TABLE 1-2 Summary Balance Sheet for DLC at End of 2015 ($ millions)

Assets		Liabilities and Net Worth	
Cash	5	Deposits	90
Marketable Securities	10	Subordinated Long-Term Debt	5
Loans	80	Equity Capital	5
Fixed Assets	5		
Total	**100**	**Total**	**100**

TABLE 1-3 Summary Income Statement for DLC in 2015 ($ millions)

Net Interest Income	3.00
Loan Losses	(0.80)
Non-Interest Income	0.90
Non-Interest Expense	(2.50)
Pre-Tax Operating Income	0.60

Table 1-2 shows that the bank has $100 million of assets. Most of the assets (80% of the total) are loans made by the bank to private individuals and small corporations. Cash and marketable securities account for a further 15% of the assets. The remaining 5% of the assets are fixed assets (i.e., buildings, equipment, etc.). A total of 90% of the funding for the assets comes from deposits of one sort or another from the bank's customers. A further 5% is financed by subordinated long-term debt. (These are bonds issued by the bank to investors that rank below deposits in the event of a liquidation.) The remaining 5% is financed by the bank's shareholders in the form of equity capital. The equity capital consists of the original cash investment of the shareholders and earnings retained in the bank.

Consider next the income statement for 2015 shown in Table 1-3. The first item on the income statement is net interest income. This is the excess of the interest earned over the interest paid and is 3% of the total assets in our example. It is important for the bank to be managed so that net interest income remains roughly constant

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regardless of movements in interest rates of different maturities.

The next item is loan losses. This is 0.8% of total assets for the year in question. Clearly it is very important for management to quantify credit risks and manage them carefully. But however carefully a bank assesses the financial health of its clients before making a loan, it is inevitable that some borrowers will default. This is what leads to loan losses. The percentage of loans that default will tend to fluctuate from year to year with economic conditions. It is likely that in some years default rates will be quite low, while in others they will be quite high.

The next item, non-interest income, consists of income from all the activities of the bank other than lending money. This includes fees for the services the bank provides for its clients. In the case of DLC non-interest income is 0.9% of assets.

The final item is non-interest expense and is 2.5% of assets in our example. This consists of all expenses other than interest paid. It includes salaries, technology-related costs, and other overheads. As in the case of all large businesses, these have a tendency to increase over time unless they are managed carefully. Banks must try to avoid large losses from litigation, business disruption, employee fraud, and so on. The risk associated with these types of losses is known as *operational risk*.

Capital Adequacy

One measure of the performance of a bank is return on equity (ROE). Tables 1-2 and 1-3 show that the DLC's before-tax ROE is *0.6/5* or 12%. If this is considered unsatisfactory, one way DLC might consider improving its ROE is by buying back its shares and replacing them with deposits so that equity financing is lower and ROE is higher. For example, if it moved to the balance sheet in Table 1-4 where equity is reduced to 1% of assets and deposits are increased to 94% of assets, its before-tax ROE would jump up to 60%.

How much equity capital does DLC need? This question can be answered by hypothesizing an extremely adverse scenario and considering whether the bank would survive. Suppose that there is a severe recession and as a result the bank's loan losses rise by 3.2% of assets to 4% next year. (We assume that other items on the income statement in Table 1-3 are unaffected.) The result will be a pre-tax net operating loss of 2.6% of assets (0.6 − 3.2 = −2.6). Assuming a tax rate of 30%, this would result in an after-tax loss of about 1.8% of assets.

TABLE 1-4 Alternative Balance Sheet for DLC at End of 2015 with Equity Only 1% of Assets ($ millions)

Assets		**Liabilities and Net Worth**	
Cash	5	Deposits	94
Marketable Securities	10	Subordinated Long-Term Debt	5
Loans	80	Equity Capital	1
Fixed Assets	5		
Total	**100**	**Total**	**100**

In Table 1-2, equity capital is 5% of assets and so an after-tax loss equal to 1.8% of assets, although not at all welcome, can be absorbed. It would result in a reduction of the equity capital to 3.2% of assets. Even a second bad year similar to the first would not totally wipe out the equity.

If DLC has moved to the more aggressive capital structure shown in Table 1-4, it is far less likely to survive. One year where the loan losses are 4% of assets would totally wipe out equity capital and the bank would find itself in serious financial difficulties. It would no doubt try to raise additional equity capital, but it is likely to find this difficult when in such a weak financial position. It is possible that there would be a run on the bank (where all depositors decide to withdraw funds at the same time) and the bank would be forced into liquidation. If all assets could be liquidated for book value (a big assumption), the long-term debt-holders would likely receive about $4.2 million rather than $5 million (they would in effect absorb the negative equity) and the depositors would be repaid in full.

Clearly, it is inadequate for a bank to have only 1% of assets funded by equity capital. Maintaining equity capital equal to 5% of assets as in Table 1-2 is more reasonable. Note that equity and subordinated long-term debt are both sources of capital. Equity provides the best protection against adverse events. (In our example, when the bank has $5 million of equity capital rather than $1 million it stays solvent and is unlikely to be liquidated.) Subordinated long-term debt-holders rank below depositors in

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the event of default, but subordinated debt does not provide as good a cushion for the bank as equity because it does not prevent the bank's insolvency.

Bank regulators have tried to ensure that the capital a bank keeps is sufficient to cover the risks it takes. The risks include market risks, credit risks, and operational risks. Equity capital is categorized as "Tier 1 capital" while subordinated long-term debt is categorized as "Tier 2 capital."

DEPOSIT INSURANCE

To maintain confidence in banks, government regulators in many countries have introduced guaranty programs. These typically insure depositors against losses up to a certain level.

The United States with its large number of small banks is particularly prone to bank failures. After the stock market crash of 1929 the United States experienced a major recession and about 10,000 banks failed between 1930 and 1933. Runs on banks and panics were common. In 1933, the United States government created the Federal Deposit Insurance Corporation (FDIC) to provide protection for depositors. Originally, the maximum level of protection provided was $2,500. This has been increased several times and became $250,000 per depositor per bank in October 2008. Banks pay an insurance premium that is a percentage of their domestic deposits. Since 2007, the size of the premium paid has depended on the bank's capital and how safe it is considered to he by regulators. For well-capitalized banks, the premium might be less than 0.1% of the amount insured; for under-capitalized banks, it could be over 0.35% of the amount insured.

Up to 1980, the system worked well. There were no runs on banks and few bank failures. However, between 1980 and 1990, bank failures in the United States accelerated with the total number of failures during this decade being over 1,000 (larger than for the whole 1933 to 1979 period). There were several reasons for this. One was the way in which banks managed interest rate risk and another reason was the reduction in oil and other commodity prices which led to many loans to oil, gas, and agricultural companies not being repaid.

A further reason for the bank failures was that the existence of deposit insurance allowed banks to follow risky strategies that would not otherwise be feasible. For example, they could increase their deposit base by offering high rates of interest to depositors and use the funds to make risky loans. Without deposit insurance, a bank could not follow this strategy because their depositors would see what they were doing, decide that the bank was too risky, and withdraw their funds. With deposit insurance, it can follow the strategy because depositors know that, if the worst happens, they are protected under FDIC. This is an example of what is known as *moral hazard*. It can be defined as the possibility that the existence of insurance changes the behavior of the insured party. The introduction of risk-based deposit insurance premiums has reduced moral hazard to some extent.

During the 1980s, the funds of FDIC became seriously depleted and it had to borrow $30 billion from the U.S. Treasury. In December 1991, Congress passed the FDIC Improvement Act to prevent any possibility of the fund becoming insolvent in the future. Between 1991 and 2006, bank failures in the United States were relatively rare and by 2006 the fund had reserves of about $50 billion. However, FDIC funds were again depleted by the banks that failed as a result of the credit crisis that started in 2007.

INVESTMENT BANKING

The main activity of investment banking is raising debt and equity financing for corporations or governments. This involves originating the securities, underwriting them, and then placing them with investors. In a typical arrangement a corporation approaches an investment bank indicating that it wants to raise a certain amount of finance in the form of debt, equity, or hybrid instruments such as convertible bonds. The securities are originated complete with legal documentation itemizing the rights of the security holder. A prospectus is created outlining the company's past performance and future prospects. The risks faced by the company from such things as major lawsuits are included. There is a "road show" in which the investment bank and senior management from the company attempt to market the securities to large fund managers. A price for the securities is agreed between the bank and the corporation. The bank then sells the securities in the market.

There are a number of different types of arrangement between the investment bank and the corporation. Sometimes the financing takes the form of a *private placement*

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in which the securities are sold to a small number of large institutional investors, such as life insurance companies or pension funds, and the investment bank receives a fee. On other occasions it takes the form of a *public offering*, where securities are offered to the general public. A public offering may be on a *best efforts* or *firm commitment* basis. In the case of a best efforts public offering, the investment bank does as well as it can to place the securities with investors and is paid a fee that depends, to some extent, on its success. In the case of a firm commitment public offering, the investment bank agrees to buy the securities from the issuer at a particular price and then attempts to sell them in the market for a slightly higher price. It makes a profit equal to the difference between the price at which it sells the securities and the price it pays the issuer. If for any reason it is unable to sell the securities, it ends up owning them itself. The difference between the two arrangements is illustrated in Example 1.1.

Example 1.1

A bank has agreed to underwrite an issue of 50 million shares by ABC Corporation. In negotiations between the bank and the corporation the target price to be received by the corporation has been set at $30 per share. This means that the corporation is expecting to raise 30 × 50 million dollars or $1.5 billion in total. The bank can either offer the client a best efforts arrangement where it charges a fee of $0.30 per share sold so that, assuming all shares are sold, it obtains a total fee of 0.3 × 50 = $15 million. Alternatively, it can offer a firm commitment where it agrees to buy the shares from ABC Corporation for $30 per share.

The bank is confident that it will be able to sell the shares, but is uncertain about the price. As part of its procedures for assessing risk, it considers two alternative scenarios. Under the first scenario, it can obtain a price of $32 per share; under the second scenario, it is able to obtain only $29 per share.

In a best-efforts deal, the bank obtains a fee of $15 million in both cases. In a firm commitment deal, its profit depends on the price it is able to obtain. If it sells the shares for $32, it makes a profit of (32 − 30) × 50 = $100 million because it has agreed to pay ABC Corporation $30 per share. However, if it can only sell the shares for $29 per share, it loses (30 − 29) × 50 = $50 million because it still has to pay ABC Corporation $30 per share.

The situation is summarized in the table following. The decision taken is likely to depend on the probabilities assigned by the bank to different outcomes and what is referred to as its "risk appetite."

	Profits If Best Efforts	Profits If Firm Commitment
Can sell at $29	+$15 million	−$50 million
Can sell at $32	+$15 million	+$100 million

When equity financing is being raised and the company is already publicly traded, the investment bank can look at the prices at which the company's shares are trading a few days before the issue is to be sold as a guide to the issue price. Typically it will agree to attempt to issue new shares at a target price slightly below the current price. The main risk then is that the price of the company's shares will show a substantial decline before the new shares are sold.

IPOs

When the company wishing to issue shares is not publicly traded, the share issue is known as an *initial public offering* (IPO). These types of offering are typically made on a best efforts basis. The correct offering price is difficult to determine and depends on the investment bank's assessment of the company's value. The bank's best estimate of the market price is its estimate of the company's value divided by the number of shares currently outstanding. However, the bank will typically set the offering price below its best estimate of the market price. This is because it does not want to take the chance that the issue will not sell. (It typically earns the same fee per share sold regardless of the offering price.)

Often there is a substantial increase in the share price immediately after shares are sold in an IPO (sometimes as much as 40%), indicating that the company could have raised more money if the issue price had been higher. As a result, IPOs are considered attractive buys by many investors. Banks frequently offer IPOs to the fund managers that are their best customers and to senior executives of large companies in the hope that they will provide them with business. (The latter is known as "spinning" and is frowned upon by regulators.)

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Dutch Auction Approach

A few companies have used a Dutch auction approach for their IPOs. As for a regular IPO, a prospectus is issued and usually there is a road show. Individuals and companies bid by indicating the number of shares they want and the price they are prepared to pay. Shares are first issued to the highest bidder, then to the next highest bidder, and so on, until all the shares have been sold. The price paid by all successful bidders is the lowest bid that leads to a share allocation. This is illustrated in Example 1.2.

Example 1.2

A company wants to sell one million shares in an IPO. It decides to use the Dutch auction approach. The bidders are shown in the table following. In this case, shares are allocated first to C, then to F, then to E, then to H, then to A. At this point, 800,000 shares have been allocated. The next highest bidder is D who has bid for 300,000 shares. Because only 200,000 remain unallocated, D's order is only two-thirds filled. The price paid by all the investors to whom shares are allocated (A, C, D, E, F, and H) is the price bid by D, or $29.00.

Bidder	Number of Shares	Price
A	100,000	$30.00
B	200,000	$28.00
C	50,000	$33.00
D	300,000	$29.00
E	150,000	$30.50
F	300,000	$31.50
G	400,000	$25.00
H	200,000	$30.25

Dutch auctions potentially overcome two of the problems with a traditional IPO that we have mentioned. First, the price that clears the market ($29.00 in Example 1.2) should be the market price if all potential investors have participated in the bidding process. Second, the situations where investment banks offer IPOs only to their favored clients are avoided. However, the company does not take advantage of the relationships that investment bankers have developed with large investors that usually enable the investment bankers to sell an IPO very quickly. One high profile IPO that used a Dutch auction was the Google IPO in 2004. This is discussed in Box 1-1.

Advisory Services

In addition to assisting companies with new issues of securities, investment banks offer advice to companies on mergers and acquisitions, divestments, major corporate restructurings, and so on. They will assist in finding merger partners and takeover targets or help companies find buyers for divisions or subsidiaries of which they want to divest themselves. They will also advise the management of companies which are themselves merger or takeover targets. Sometimes they suggest steps they should take to avoid a merger or takeover. These are known as *poison pills*. Examples of poison pills are:

1. A potential target adds to its charter a provision where, if another company acquires one-third of the shares, other shareholders have the right to sell their shares to that company for twice the recent average share price.
2. A potential target grants to its key employees stock options that vest (i.e., can be exercised) in the event of a takeover. This is liable to create an exodus of key employees immediately after a takeover, leaving an empty shell for the new owner.
3. A potential target adds to its charter provisions making it impossible for a new owner to get rid of existing directors for one or two years after an acquisition.
4. A potential target issues preferred shares that automatically get converted to regular shares when there is a change in control.
5. A potential target adds a provision where existing shareholders have the right to purchase shares at a discounted price during or after a takeover.
6. A potential target changes the voting structure so that shares owned by management have more votes than those owned by others.

Poison pills, which are illegal in many countries outside the United States, have to be approved by a majority of shareholders. Often shareholders oppose poison pills because they see them as benefiting only management. An unusual poison pill, tried by PeopleSoft to fight a takeover by Oracle, is explained in Box 1-2.

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BOX 1-1 Google's IPO

Google, developer of the well-known Internet search engine, decided to go public in 2004. It chose the Dutch auction approach. It was assisted by two investment banks, Morgan Stanley and Credit Suisse First Boston. The SEC gave approval for it to raise funds up to a maximum of $2,718,281,828. (Why the odd number? The mathematical constant e is 2.7182818 . . .) The IPO method was not a pure Dutch auction because Google reserved the right to change the number of shares that would be issued and the percentage allocated to each bidder when it saw the bids.

Some investors expected the price of the shares to be as high as $120. But when Google saw the bids, it decided that the number of shares offered would be 19,605,052 at a price of $85. This meant that the total value of the offering was 19,605,052 x 85 or $1.67 billion. Investors who had bid $85 or above obtained 74.2% of the shares they had bid for. The date of the IPO was August 19, 2004. Most companies would have given investors who bid $85 or more 100% of the amount they bid for and raised $2.25 billion, instead of $1.67 billion. Perhaps Google (stock symbol: GOOG) correctly anticipated it would have no difficulty in selling further shares at a higher price later.

The initial market capitalization was $23.1 billion with over 90% of the shares being held by employees. These employees included the founders, Sergei Brin and Larry Page, and the CEO, Eric Schmidt. On the first day of trading, the shares closed at $100.34, 18% above the offer price and there was a further 7% increase on the second day. Google's issue therefore proved to be underpriced—but not as underpriced as some other IPOs of technology stocks where traditional IPO methods were used.

The cost of Google's IPO (fees paid to investment banks, etc.) was 2.8% of the amount raised. This compares with an average of about 4% for a regular IPO.

There were some mistakes made and Google was lucky that these did not prevent the IPO from going ahead as planned. Sergei Brin and Larry Page gave an interview to *Playboy* magazine in April 2004. The interview appeared in the September issue. This violated SEC requirements that there be a "quiet period" with no promoting of the company's stock in the period leading up to an IPO. To avoid SEC sanctions, Google had to include the *Playboy* interview (together with some factual corrections) in its SEC filings. Google also forgot to register 23.2 million shares and 5.6 million stock options.

Google's stock price rose rapidly in the period after the IPO. Approximately one year later (in September 2005) it was able to raise a further $4.18 billion by issuing an additional 14,159,265 shares at $295. (Why the odd number? The mathematical constant π is 3.14159265 . . .)

BOX 1-2 PeopleSoft's Poison Pill

In 2003, the management of PeopleSoft, Inc., a company that provided human resource management systems, was concerned about a takeover by Oracle, a company specializing in database management systems. It took the unusual step of guaranteeing to its customers that, if it were acquired within two years and product support was reduced within four years, its customers would receive a refund of between two and five times the fees paid for their software licenses. The hypothetical cost to Oracle was estimated at $1.5 billion. The guarantee was opposed by PeopleSoft's shareholders. (It appears to be not in their interests.) PeopleSoft discontinued the guarantee in April 2004.

Oracle did succeed in acquiring PeopleSoft in December 2004. Although some jobs at PeopleSoft were eliminated, Oracle maintained at least 90% of PeopleSoft's product development and support staff.

Valuation, strategy, and tactics are key aspects of the advisory services offered by an investment bank. For example, in advising Company A on a potential takeover of Company B, it is necessary for the investment bank to value Company B and help Company A assess possible synergies between the operations of the two companies. It must also consider whether it is better to offer Company B's shareholders cash or a share-for-share exchange (i.e., a certain number of shares in Company A in exchange for each share of Company B). What should the initial offer be? What does it expect the final offer that will close the deal to be? It must assess the best way to approach the senior managers of Company B and consider what the motivations of the managers will be. Will the takeover be a hostile one (opposed by the management of Company B) or friendly one (supported by the

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management of Company B)? In some instances there will be antitrust issues and approval from some branch of government may be required.

SECURITIES TRADING

Banks often get involved in securities trading, providing brokerage services, and making a market in individual securities. In doing so, they compete with smaller securities firms that do not offer other banking services. As mentioned earlier, the Dodd-Frank act in the United States does not allow banks to engage in proprietary trading. In some other countries, proprietary trading is allowed, but it usually has to be organized so that losses do not affect depositors.

Most large investment and commercial banks have extensive trading activities. Apart from proprietary trading (which may or may not be allowed), banks trade to provide services to their clients. (For example, a bank might enter into a derivatives transaction with a corporate client to help it reduce its foreign exchange risk.) They also trade (typically with other financial institutions) to hedge their risks.

A broker assists in the trading of securities by taking orders from clients and arranging for them to be carried out on an exchange. Some brokers operate nationally, and some serve only a particular region. Some, known as full-service brokers, offer investment research and advice. Others, known as discount brokers, charge lower commissions, but provide no advice. Some offer online services, and some, such as E*Trade, provide a platform for customers to trade without a broker.

A market maker facilitates trading by always being prepared to quote a bid (the price at which it is prepared to buy) and an offer (the price at which it is prepared to sell). When providing a quote, it does not know whether the person requesting the quote wants to buy or sell. The market maker makes a profit from the spread between the bid and the offer, but takes the risk that it will be left with an unacceptably high exposure.

Many exchanges on which stocks, options, and futures trade use market makers. Typically, an exchange will specify a maximum level for the size of a market maker's bid-offer spread (the difference between the offer and the bid). Banks have in the past been market makers for instruments such as forward contracts, swaps, and options trading in the over-the-counter (OTC) market. The trading and market making of these types of instruments is now increasingly being carried out on electronic platforms that are known as swap execution facilities (SEFs) in the United States and organized trading facilities (OTFs) in Europe.

POTENTIAL CONFLICTS OF INTEREST IN BANKING

There are many potential conflicts of interest between commercial banking, securities services, and investment banking when they are all conducted under the same corporate umbrella. For example:

1. When asked for advice by an investor, a bank might be tempted to recommend securities that the investment banking part of its organization is trying to sell. When it has a fiduciary account (i.e., a customer account where the bank can choose trades for the customer), the bank can "stuff" difficult-to-sell securities into the account.
2. A bank, when it lends money to a company, often obtains confidential information about the company. It might be tempted to pass that information to the mergers and acquisitions arm of the investment bank to help it provide advice to one of its clients on potential takeover opportunities.
3. The research end of the securities business might be tempted to recommend a company's share as a "buy" in order to please the company's management and obtain investment banking business.
4. Suppose a commercial bank no longer wants a loan it has made to a company on its books because the confidential information it has obtained from the company leads it to believe that there is an increased chance of bankruptcy. It might be tempted to ask the investment bank to arrange a bond issue for the company, with the proceeds being used to pay off the loan. This would have the effect of replacing its loan with a loan made by investors who were less well-informed.

As a result of these types of conflicts of interest, some countries have in the past attempted to separate commercial banking from investment banking. The Glass-Steagall Act of 1933 in the United States limited the ability of commercial banks and investment banks to engage in

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each other's activities. Commercial banks were allowed to continue underwriting Treasury instruments and some municipal bonds. They were also allowed to do private placements. But they were not allowed to engage in other activities such as public offerings. Similarly, investment banks were not allowed to take deposits and make commercial loans.

In 1987, the Federal Reserve Board relaxed the rules somewhat and allowed banks to establish holding companies with two subsidiaries, one in investment banking and the other in commercial banking, The revenue of the investment banking subsidiary was restricted to being a certain percentage of the group's total revenue.

In 1997, the rules were relaxed further so that commercial banks could acquire existing investment banks. Finally, in 1999, the Financial Services Modernization Act was passed. This effectively eliminated all restrictions on the operations of banks, insurance companies, and securities firms. In 2007, there were five large investment banks in the United States that had little or no commercial banking interests. These were Goldman Sachs, Morgan Stanley, Merrill Lynch, Bear Stearns, and Lehman Brothers. In 2008, the credit crisis led to Lehman Brothers going bankrupt, Bear Stearns being taken over by JPMorgan Chase, and Merrill Lynch being taken over by Bank of America. Goldman Sachs and Morgan Stanley became bank holding companies with both commercial and investment banking interests. (As a result, they have had to subject themselves to more regulatory scrutiny.) The year 2008 therefore marked the end of an era for investment banking in the United States.

We have not returned to the Glass-Steagall world where investment banks and commercial banks were kept separate. But increasingly banks are required to ring fence their deposit-taking businesses so that they cannot be affected by losses in investment banking.

TODAY'S LARGE BANKS

Today's large banks operate globally and transact business in many different areas. They are still engaged in the traditional commercial banking activities of taking deposits, making loans, and clearing checks (both nationally and internationally). They offer retail customers credit cards, telephone banking, Internet banking, and automatic teller machines (ATMs). They provide payroll services to businesses and, as already mentioned, they have large trading activities.

Banks offer lines of credit to businesses and individual customers. They provide a range of services to companies when they are exporting goods and services. Companies can enter into a variety of contracts with banks that are designed to hedge risks they face relating to foreign exchange, commodity prices, interest rates, and other market variables. Even risks related to the weather can be hedged.

Banks undertake securities research and offer "buy," "sell," and "hold" recommendations on individual stocks. They offer brokerage services (discount and full service). They offer trust services where they are prepared to manage portfolios of assets for clients. They have economics departments that consider macroeconomic trends and actions likely to be taken by central banks. These departments produce forecasts on interest rates, exchange rates, commodity prices, and other variables. Banks offer a range of mutual funds and in some cases have their own hedge funds. Increasingly banks are offering insurance products.

The investment banking arm of a bank has complete freedom to underwrite securities for governments and corporations. It can provide advice to corporations on mergers and acquisitions and other topics relating to corporate finance.

There are internal barriers known as *Chinese walls*. These internal barriers prohibit the transfer of information from one part of the bank to another when this is not in the best interests of one or more of the bank's customers. There have been some well-publicized violations of conflict-of-interest rules by large banks. These have led to hefty fines and lawsuits. Top management has a big incentive to enforce Chinese walls. This is not only because of the fines and lawsuits. A bank's reputation is its most valuable asset. The adverse publicity associated with conflict-of-interest violations can lead to a loss of confidence in the bank and business being lost in many different areas.

Accounting

It is appropriate at this point to provide a brief discussion of how a bank calculates a profit or loss from its many diverse activities. Activities that generate fees, such as most investment banking activities, are straightforward.

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Accrual accounting rules similar to those that would be used by any other business apply.

For other banking activities, there is an important distinction between the "banking book" and the "trading book." As its name implies, the trading book includes all the assets and liabilities the bank has as a result of its trading operations. The values of these assets and liabilities are *marked to market* daily. This means that the value of the book is adjusted daily to reflect changes in market prices. If a bank trader buys an asset for $100 on one day and the price falls to $60 the next day, the bank records an immediate loss of $40—even if it has no intention of selling the asset in the immediate future. Sometimes it is not easy to estimate the value of a contract that has been entered into because there are no market prices for similar transactions. For example, there might be a lack of liquidity in the market or it might be the case that the transaction is a complex nonstandard derivative that does not trade sufficiently frequently for benchmark market prices to be available. Banks are nevertheless expected to come up with a market price in these circumstances. Often a model has to be assumed. The process of coming up with a "market price" is then sometimes termed *marking to model.*

The banking book includes loans made to corporations and individuals. These are not marked to market. If a borrower is up-to-date on principal and interest payments on a loan, the loan is recorded in the bank's books at the principal amount owed plus accrued interest. If payments due from the borrower are more than 90 days past due, the loan is usually classified as a *non-performing loan.* The bank does not then accrue interest on the loan when calculating its profit. When problems with the loan become more serious and it becomes likely that principal will not be repaid, the loan is classified as a loan loss.

A bank creates a reserve for loan losses. This is a charge against the income statement for an estimate of the loan losses that will be incurred. Periodically the reserve is increased or decreased. A bank can smooth out its income from one year to the next by overestimating reserves in good years and underestimating them in bad years. Actual loan losses are charged against reserves. Occasionally, as described in Box 1-3, a bank resorts to artificial ways of avoiding the recognition of loan losses.

The Originate-to-Distribute Model

DLC, the small hypothetical bank we looked at in Tables 1-2 to 1-4, took deposits and used them to finance loans. An alternative approach is known as the *originate-to-distribute model.* This involves the bank originating but

BOX 1-3 How to Keep Loans Performing

When a borrower is experiencing financial difficulties and is unable to make interest and principal payments as they become due, it is sometimes tempting to lend more money to the borrower so that the payments on the old loans can be kept up to date. This is an accounting game, sometimes referred to *debt rescheduling.* It allows interest on the loans to be accrued and avoids (or at least defers) the recognition of loan losses.

In the 1970s, banks in the United States and other countries lent huge amounts of money to Eastern European, Latin American, and other less developed countries (LDCs). Some of the loans were made to help countries develop their infrastructure, but others were less justifiable (e.g., one was to finance the coronation of a ruler in Africa). Sometimes the money found its way into the pockets of dictators. For example, the Marcos family in the Philippines allegedly transferred billions of dollars into its own bank accounts.

In the early 1980s, many LDCs were unable to service their loans. One option for them was *debt repudiation,* but a more attractive alternative was debt rescheduling. In effect, this leads to the interest on the loans being capitalized and bank funding requirements for the loans to increase. Well-informed LDCs were aware of the desire of banks to keep their LDC loans performing so that profits looked strong. They were therefore in a strong negotiating position as their loans became 90 days overdue and banks were close to having to produce their quarterly financial statements.

In 1987, Citicorp (now Citigroup) took the lead in refusing to reschedule LDC debt and increased its loan loss reserves by $3 billion in recognition of expected losses on the debt. Other banks with large LDC exposures followed suit.

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not keeping loans. Portfolios of loans are packaged into tranches which are then sold to investors.

The originate-to-distribute model has been used in the U.S. mortgage market for many years. In order to increase the liquidity of the U.S. mortgage market and facilitate the growth of home ownership, three government sponsored entities have been created: the Government National Mortgage Association (GNMA) or "Ginnie Mae," the Federal National Mortgage Association (FNMA) or "Fannie Mae," and the Federal Home Loan Mortgage Corporation (FHLMC) or "Freddie Mac." These agencies buy pools of mortgages from banks and other mortgage originators, guarantee the timely repayment of interest and principal, and then package the cash flow streams and sell them to investors. The investors typically take what is known as prepayment risk. This is the risk that interest rates will decrease and mortgages will be paid off earlier than expected. However, they do not take any credit risk because the mortgages are guaranteed by GNMA, FNMA, or FHLMC. In 1999, FNMA and FHLMC started to guarantee subprime loans and as a result ran into serious financial difficulties.[1]

The originate-to-distribute model has been used for many types of bank lending including student loans, commercial loans, commercial mortgages, residential mortgages, and credit card receivables. In many cases there is no guarantee that payment will be made so that it is the investors that bear the credit risk when the loans are packaged and sold.

The originate-to-distribute model is also termed *securitization* because securities are created from cash flow streams originated by the bank. It is an attractive model for banks. By securitizing its loans it gets them off the balance sheet and frees up funds to enable it to make more loans. It also frees up capital that can be used to cover risks being taken elsewhere in the bank. (This is particularly attractive if the bank feels that the capital required by regulators for a loan is too high.) A bank earns a fee for originating a loan and a further fee if it services the loan after it has been sold.

[1] GNMA has always been government owned whereas FNMA and FHLMC used to be private corporations with shareholders. As a result of their financial difficulties in 2008, the U.S. government had to step in and assume complete control of FNMA and FHLMC.

The originate-to-distribute model got out of control during the 2000 to 2006 period. Banks relaxed their mortgage lending standards and the credit quality of the instruments being originated declined sharply. This led to a severe credit crisis and a period during which the originate-to-distribute model could not be used by banks because investors had lost confidence in the securities that had been created.

THE RISKS FACING BANKS

A bank's operations give rise to many risks. Much of the rest of this book is devoted to considering these risks in detail.

Central bank regulators require banks to hold capital for the risks they are bearing. In 1988, international standards were developed for the determination of this capital. Capital is now required for three types of risk: credit risk, market risk, and operational risk.

Credit risk is the risk that counterparties in loan transactions and derivatives transactions will default. This has traditionally been the greatest risk facing a bank and is usually the one for which the most regulatory capital is required. Market risk arises primarily from the bank's trading operations. It is the risk relating to the possibility that instruments in the bank's trading book will decline in value. Operational risk, which is often considered to be the biggest risk facing banks, is the risk that losses are made because internal systems fail to work as they are supposed to or because of external events. The time horizon used by regulators for considering losses from credit risks and operational risks is one year, whereas the time horizon for considering losses from market risks is usually much shorter. The objective of regulators is to keep the total capital of a bank sufficiently high that the chance of a bank failure is very low. For example, in the case of credit risk and operational risk, the capital is chosen so that the chance of unexpected losses exceeding the capital in a year is 0.1%.

In addition to calculating regulatory capital, most large banks have systems in place for calculating what is termed *economic capital*. This is the capital that the bank, using its own models rather than those prescribed by regulators, thinks it needs. Economic capital is often less than regulatory capital. However, banks have no choice but to maintain their capital above the regulatory capital

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level. The form the capital can take (equity, subordinated debt, etc.) is prescribed by regulators. To avoid having to raise capital at short notice, banks try to keep their capital comfortably above the regulatory minimum.

When banks announced huge losses on their subprime mortgage portfolios in 2007 and 2008, many had to raise new equity capital in a hurry. *Sovereign wealth funds*, which are investment funds controlled by the government of a country, have provided some of this capital. For example, Citigroup, which reported losses in the region of $40 billion, raised $7.5 billion in equity from the Abu Dhabi Investment Authority in November 2007 and $14.5 billion from investors that included the governments of Singapore and Kuwait in January 2008. Later, Citigroup and many other banks required capital injections from their own governments to survive.

SUMMARY

Banks are complex global organizations engaged in many different types of activities. Today, the world's large banks are engaged in taking deposits, making loans, underwriting securities, trading, providing brokerage services, providing fiduciary services, advising on a range of corporate finance issues, offering mutual funds, providing services to hedge funds, and so on. There are potential conflicts of interest and banks develop internal rules to avoid them. It is important that senior managers are vigilant in ensuring that employees obey these rules. The cost in terms of reputation, lawsuits, and fines from inappropriate behavior where one client (or the bank) is advantaged at the expense of another client can be very large.

There are now international agreements on the regulation of banks. This means that the capital banks are required to keep for the risks they are bearing does not vary too much from one country to another. Many countries have guaranty programs that protect small depositors from losses arising from bank failures. This has the effect of maintaining confidence in the banking system and avoiding mass withdrawals of deposits when there is negative news (or perhaps just a rumor) about problems faced by a particular bank.

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Insurance Companies and Pension Plans

2

Learning Objectives

After completing this reading you should be able to:

- Describe the key features of the various categories of insurance companies and identify the risks facing insurance companies.
- Describe the use of mortality tables and calculate the premium payment for a policy holder.
- Calculate and interpret loss ratio, expense ratio, combined ratio, and operating ratio for a property-casualty insurance company.
- Describe moral hazard and adverse selection risks facing insurance companies, provide examples of each, and describe how to overcome the problems.
- Distinguish between mortality risk and longevity risk and describe how to hedge these risks.
- Evaluate the capital requirements for life insurance and property-casualty insurance companies.
- Compare the guaranty system and the regulatory requirements for insurance companies with those for banks.
- Describe a defined benefit plan and a defined contribution plan for a pension fund and explain the differences between them.

Excerpt is from Chapter 3 of Risk Management and Financial Institutions, 4th Edition, *by John Hull.*

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The role of insurance companies is to provide protection against adverse events. The company or individual seeking protection is referred to as the *policyholder*. The policyholder makes regular payments, known as *premiums*, and receives payments from the insurance company if certain specified events occur. Insurance is usually classified as *life insurance* and *nonlife insurance*, with health insurance often being considered to be a separate category. Nonlife insurance is also referred to as *property-casualty insurance* and this is the terminology we will use here.

A life insurance contract typically lasts a long time and provides payments to the policyholder's beneficiaries that depend on when the policyholder dies. A property-casualty insurance contract typically lasts one year (although it may be renewed) and provides compensation for losses from accidents, fire, theft, and so on.

Insurance has existed for many years. As long ago as 200 B.C., there was an arrangement in ancient Greece where an individual could make a lump sum payment (the amount dependent on his or her age) and obtain a monthly income for life. The Romans had a form of life insurance where an individual could purchase a contract that would provide a payment to relatives on his or her death. In ancient China, a form of property-casualty insurance existed between merchants where, if the ship of one merchant sank, the rest of the merchants would provide compensation.

A pension plan is a form of insurance arranged by a company for its employees. It is designed to provide the employees with income for the rest of their lives once they have retired. Typically both the company and its employees make regular monthly contributions to the plan and the funds in the plan are invested to provide income for retirees.

This chapter describes how the contracts offered by insurance companies work. It explains the risks that insurance companies face and the way they are regulated. It also discusses key issues associated with pension plans.

LIFE INSURANCE

In life insurance contracts, the payments to the policyholder depend—at least to some extent—on when the policyholder dies. Outside the United States, the term *life assurance* is often used to describe a contract where the event being insured against is certain to happen at some future time (e.g., a contract that will pay $100,000 on the policyholder's death). Life insurance is used to describe a contract where the event being insured against may never happen (for example, a contract that provides a payoff in the event of the accidental death of the policyholder.)[1] In the United States, all types of life policies are referred to as life insurance and this is the terminology that will be adopted here.

There are many different types of life insurance products. The products available vary from country to country. We will now describe some of the more common ones.

Term Life Insurance

Term life insurance (sometimes referred to as *temporary life insurance*) lasts a predetermined number of years. If the policyholder dies during the life of the policy, the insurance company makes a payment to the specified beneficiaries equal to the face amount of the policy. If the policyholder does not die during the term of the policy, no payments are made by the insurance company. The policyholder is required to make regular monthly or annual premium payments to the insurance company for the life of the policy or until the policyholder's death (whichever is earlier). The face amount of the policy typically stays the same or declines with the passage of time. One type of policy is an *annual renewable term* policy. In this, the insurance company guarantees to renew the policy from one year to the next at a rate reflecting the policyholder's age without regard to the policyholder's health.

A common reason for term life insurance is a mortgage. For example, a person aged 35 with a 25-year mortgage might choose to buy 25-year term insurance (with a declining face amount) to provide dependents with the funds to pay off the mortgage in the event of his or her death.

Whole Life Insurance

Whole life insurance (sometimes referred to as *permanent life insurance*) provides protection for the life of the policyholder. The policyholder is required to make regular

[1] In theory, for a contract to be referred to as life assurance, it is the event being insured against that must be certain to occur. It does not need to be the case that a payout is certain. Thus a policy that pays out if the policyholder dies in the next 10 years is life assurance. In practice, this distinction is sometimes blurred.

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monthly or annual payments until his or her death. The face value of the policy is then paid to the designated beneficiary. In the case of term life insurance, there is no certainty that there will be a payout, but in the case of whole life insurance, a payout is certain to happen providing the policyholder continues to make the agreed premium payments. The only uncertainty is when the payout will occur. Not surprisingly, whole life insurance requires considerably higher premiums than term life insurance policies. Usually, the payments and the face value of the policy both remain constant through time.

Policyholders can often redeem (surrender) whole life policies early or use the policies as collateral for loans. When a policyholder wants to redeem a whole life policy early, it is sometimes the case that an investor will buy the policy from the policyholder for more than the surrender value offered by the insurance company. The investor will then make the premium payments and collect the face value from the insurance company when the policyholder dies.

The annual premium for a year can be compared with the cost of providing term life insurance for that year. Consider a man who buys a $1 million whole life policy at the age of 40. Suppose that the premium is $20,000 per year. As we will see later, the probability of a male aged 40 dying within one year is about 0.0022, suggesting that a fair premium for one-year insurance is about $2,200. This means that there is a *surplus premium* of $17,800 available for investment from the first year's premium. The probability of a man aged 41 dying in one year is about 0.0024, suggesting that a fair premium for insurance during the second year is $2,400. This means that there is a $17,600 surplus premium available for investment from the second year's premium. The cost of a one-year policy continues to rise as the individual gets older so that at some stage it is greater than the annual premium. In our example, this would have happened by the 30th year because the probability of a man aged 70 dying in one year is 0.0245. (A fair premium for the 30th year is $24,500, which is more than the $20,000 received.) The situation is illustrated in Figure 2-1. The surplus during the early years is used to fund the deficit during later years. There is a savings element to whole life insurance. In the early years, the part of the premium not needed to cover the risk of a payout is invested on behalf of the policyholder by the insurance company.

There are tax advantages associated with life insurance policies in many countries. If the policyholder invested the surplus premiums, tax would normally be payable on the income as it was earned. But, when the surplus premiums are invested within the insurance policy, the tax treatment is often better. Tax is deferred, and sometimes the payout to the beneficiaries of life insurance policies is free of income tax altogether.

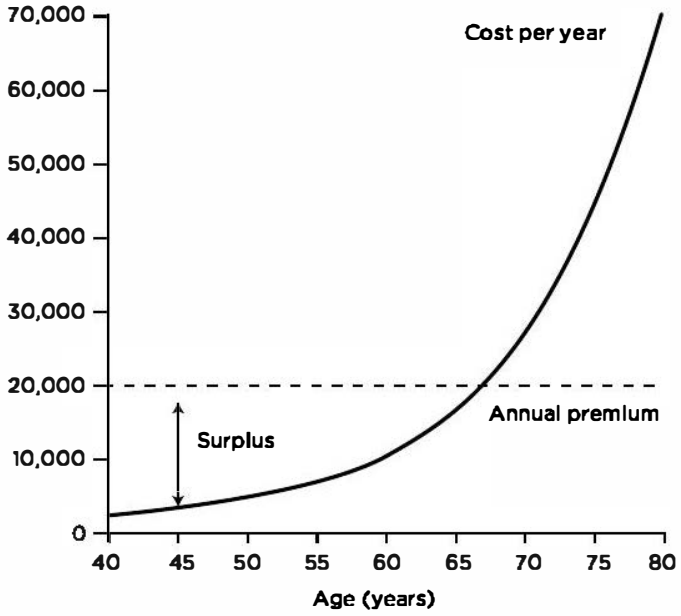

FIGURE 2-1 Cost of life insurance per year compared with the annual premium in a whole life contract.

Variable Life Insurance

Given that a whole life insurance policy involves funds being invested for the policyholder, a natural development is to allow the policyholder to specify how the funds are invested. Variable life (VL) insurance is a form of whole life insurance where the surplus premiums discussed earlier are invested in a fund chosen by the policyholder. This could be an equity fund, a bond fund, or a money market fund. A minimum guaranteed payout on death is usually specified, but the payout can be more if the fund does well. Income earned from the investments can sometimes be applied toward the premiums. The policyholder can usually switch from one fund to another at any time.

Universal Life

Universal life (UL) insurance is also a form of whole life insurance. The policyholder can reduce the premium down to a specified minimum without the policy lapsing. The

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surplus premiums are invested by the insurance company in fixed income products such as bonds, mortgages, and money market instruments. The insurance company guarantees a certain minimum return, say 4%, on these funds. The policyholder can choose between two options. Under the first option, a fixed benefit is paid on death; under the second option, the policyholder's beneficiaries receive more than the fixed benefit if the investment return is greater than the guaranteed minimum. Needless to say, premiums are lower for the first option.

Variable-Universal Life Insurance

Variable-universal life (VUL) insurance blends the features found in variable life insurance and universal life insurance. The policyholder can choose between a number of alternatives for the investment of surplus premiums. The insurance company guarantees a certain minimum death benefit and interest on the investments can sometimes be applied toward premiums. Premiums can be reduced down to a specified minimum without the policy lapsing.

Endowment Life Insurance

Endowment life insurance lasts for a specified period and pays a lump sum either when the policyholder dies or at the end of the period, whichever is first. There are many different types of endowment life insurance contracts. The amount that is paid out can be specified in advance as the same regardless of whether the policyholder dies or survives to the end of the policy. Sometimes the payout is also made if the policyholder has a critical illness. In a *with-profits* endowment life insurance policy, the insurance company declares periodic bonuses that depend on the performance of the insurance company's investments. These bonuses accumulate to increase the amount paid out to the policyholder, assuming the policyholder lives beyond the end of the life of the policy. In a unit-linked endowment, the amount paid out at maturity depends on the performance of the fund chosen by the policyholder. A *pure endowment* policy has the property that a payout occurs only if the policyholder survives to the end of the life of the policy.

Group Life Insurance

Group life insurance covers many people under a single policy. It is often purchased by a company for its employees. The policy may be *contributory*, where the premium payments are shared by the employer and employee, or *noncontributory*, where the employer pays the whole of the cost. There are economies of scale in group life insurance. The selling and administration costs are lower. An individual is usually required to undergo medical tests when purchasing life insurance in the usual way, but this may not be necessary for group life insurance. The insurance company knows that it will be taking on some better-than-average risks and some worse-than-average risks.

ANNUITY CONTRACTS

Many life insurance companies also offer annuity contracts. Where a life insurance contract has the effect of converting regular payments into a lump sum, an annuity contract has the opposite effect: that of converting a lump sum into regular payments. In a typical arrangement, the policyholder makes a lump sum payment to the insurance company and the insurance company agrees to provide the policyholder with an annuity that starts at a particular date and lasts for the rest of the policyholder's life. In some instances, the annuity starts immediately after the lump sum payment by the policyholder. More usually, the lump sum payment is made by the policyholder several years ahead of the time when the annuity is to start and the insurance company invests the funds to create the annuity. (This is referred to as a *deferred annuity*.) Instead of a lump sum, the policyholder sometimes saves for the annuity by making regular monthly, quarterly, or annual payments to the insurance company.

There are often tax deferral advantages to the policyholder. This is because taxes usually have to be paid only when the annuity income is received. The amount to which the funds invested by the insurance company on behalf of the policyholder have grown in value is sometimes referred to as the *accumulation value*. Funds can usually be withdrawn early, but there are liable to be penalties. In other words, the surrender value of an annuity contract is typically less than the accumulation value. This is because the insurance company has to recover selling and administration costs. Policies sometimes allow *penalty-free withdrawals* where a certain percentage of the accumulation value or a certain percentage of the original investment can be withdrawn in a year without penalty. In the event that the policyholder dies before the start of the annuity (and sometimes in other circumstances such as when the

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policyholder is admitted to a nursing home), the full accumulation value can often be withdrawn without penalty.

Some deferred annuity contracts in the United States have embedded options. The accumulation value is sometimes calculated so that it tracks a particular equity index such as the S&P 500. Lower and upper limits are specified. If the growth in the index in a year is less than the lower limit, the accumulation value grows at the lower limit rate; if it is greater than the upper limit, the accumulation value grows at the upper limit rate; otherwise it grows at the same rate as the S&P 500. Suppose that the lower limit is 0% and the upper limit is 8%. The policyholder is assured that the accumulation value will never decline, but index growth rates in excess of 8% are given up. In this type of arrangement, the policyholder is typically not compensated for dividends that would be received from an investment in the stocks underlying the index and the insurance company may be able to change parameters such as the lower limit and the upper limit from one year to the next. These types of contracts appeal to investors who want an exposure to the equity market but are reluctant to risk a decline in their accumulation value. Sometimes, the way the accumulation value grows from one year to the next is a quite complicated function of the performance of the index during the year.

In the United Kingdom, the annuity contracts offered by insurance companies used to guarantee a minimum level for the interest rate used for the calculation of the size of the annuity payments. Many insurance companies regarded this guarantee—an interest rate option granted to the policyholder—as a necessary marketing cost and did not calculate the cost of the option or hedge their risks. As interest rates declined and life expectancies increased, many insurance companies found themselves in financial difficulties and, as described in Box 2-1, at least one of them went bankrupt.

MORTALITY TABLES

Mortality tables are the key to valuing life insurance contracts. Table 2-1 shows an extract from the mortality rates estimated by the U.S. Department of Social Security for 2009. To understand the table, consider the row corresponding to age 31. The second column shows that the probability of a man who has just reached age 31 dying within the next year is 0.001445 (or 0.1445%). The third column shows that the probability of a man surviving to age 31 is 0.97234 (or 97.234%). The fourth column shows that a man aged 31 has a remaining life expectancy of 46.59 years. This means that on average he will live to age 77.59. The remaining three columns show similar statistics for a woman. The probability of a 31-year-old woman dying within one year is 0.000699 (0.0699%), the probability of a woman surviving to age 31 is 0.98486 (98.486%), and the remaining life expectancy for a 31-year-old woman is 50.86 years.

The full table shows that the probability of death during the following year is a decreasing function of age for the

BOX 2-1 Equitable Life

Equitable Life was a British life insurance company founded in 1762 that at its peak had 1.5 million policyholders. Starting in the 1950s, Equitable Life sold annuity products where it guaranteed that the interest rate used to calculate the size of the annuity payments would be above a certain level. (This is known as a Guaranteed Annuity Option, GAO.) The guaranteed interest rate was gradually increased in response to competitive pressures and increasing interest rates. Toward the end of 1993, interest rates started to fall. Also, life expectancies were rising so that the insurance companies had to make increasingly high provisions for future payouts on contracts. Equitable Life did not take action. Instead, it grew by selling new products. In 2000, it was forced to close its doors to new business. A report issued by Ann Abraham in July 2008 was highly critical of regulators and urged compensation for policyholders.

An interesting aside to this is that regulators did at one point urge insurance companies that offered GAOs to hedge their exposures to an interest rate decline. As a result, many insurance companies scrambled to enter into contracts with banks that paid off if long-term interest rates declined. The banks in turn hedged their risk by buying instruments such as bonds that increased in price when rates fell. This was done on such a massive scale that the extra demand for bonds caused long-term interest rates in the UK to decline sharply (increasing losses for insurance companies on the unhedged part of their exposures). This shows that when large numbers of different companies have similar exposures, problems are created if they all decide to hedge at the same time. There are not likely to be enough investors willing to take on their risks without market prices changing.

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TABLE 2-1 Mortality Table

Age (Years)	Male			Female		
	Probability of Death within 1 Year	Survival Probability	Life Expectancy	Probability of Death within 1 Year	Survival Probability	Life Expectancy
0	0.006990	1.00000	75.90	0.005728	1.00000	80.81
1	0.000447	0.99301	75.43	0.000373	0.99427	80.28
2	0.000301	0.99257	74.46	0.000241	0.99390	79.31
3	0.000233	0.99227	73.48	0.000186	0.99366	78.32
...	...	...	...	...	...	...
30	0.001419	0.97372	47.52	0.000662	0.98551	51.82
31	0.001445	0.97234	46.59	0.000699	0.98486	50.86
32	0.001478	0.97093	45.65	0.000739	0.98417	49.89
33	0.001519	0.96950	44.72	0.000780	0.98344	48.93
...	...	...	...	...	...	...
40	0.002234	0.95770	38.23	0.001345	0.97679	42.24
41	0.002420	0.95556	37.31	0.001477	0.97547	41.29
42	0.002628	0.95325	36.40	0.001624	0.97403	40.35
43	0.002860	0.95074	35.50	0.001789	0.97245	39.42
...	...	...	...	...	...	...
50	0.005347	0.92588	29.35	0.003289	0.95633	33.02
51	0.005838	0.92093	28.50	0.003559	0.95319	32.13
52	0.006337	0.91555	27.66	0.003819	0.94980	31.24
53	0.006837	0.90975	26.84	0.004059	0.94617	30.36
...	...	...	...	...	...	...
60	0.011046	0.85673	21.27	0.006696	0.91375	24.30
61	0.011835	0.84726	20.50	0.007315	0.90763	23.46
62	0.012728	0.83724	19.74	0.007976	0.90099	22.63
63	0.013743	0.82658	18.99	0.008676	0.89380	21.81
...	...	...	...	...	...	...
70	0.024488	0.72875	14.03	0.016440	0.82424	16.33
71	0.026747	0.71090	13.37	0.018162	0.81069	15.59
72	0.029212	0.69189	12.72	0.020019	0.79597	14.87
73	0.031885	0.67168	12.09	0.022003	0.78003	14.16
...	...	...	...	...	...	...
80	0.061620	0.49421	8.10	0.043899	0.62957	9.65
81	0.068153	0.46376	7.60	0.048807	0.60194	9.07
82	0.075349	0.43215	7.12	0.054374	0.57256	8.51
83	0.083230	0.39959	6.66	0.060661	0.54142	7.97
...	...	...	...	...	...	...
90	0.168352	0.16969	4.02	0.131146	0.28649	4.85
91	0.185486	0.14112	3.73	0.145585	0.24892	4.50
92	0.203817	0.11495	3.46	0.161175	0.21268	4.19
93	0.223298	0.09152	3.22	0.177910	0.17840	3.89

Source: U.S. Department of Social Security, www.ssa.gov/OACT/STATS/table4c6.html.

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first 10 years of life and then starts to increase. Mortality statistics for women are a little more favorable than for men. If a man is lucky enough to reach age 90, the probability of death in the next year is about 16.8%. The full table shows this probability is about 35.4% at age 100 and 57.6% at age 110. For women, the corresponding probabilities are 13.1 %, 29.9%, and 53.6%, respectively.

Some numbers in the table can be calculated from other numbers. The third column of the table shows that the probability of a man surviving to 90 is 0.16969. The probability of the man surviving to 91 is 0.14112. It follows that the probability of a man dying between his 90th and 91st birthday is 0.16969 − 0.14112 = 0.02857.

Conditional on a man reaching the age of 90, the probability that he will die in the course of the following year is therefore

$$\frac{0.02857}{0.16969} = 0.1684$$

This is consistent with the number given in the second column of the table.

The probability of a man aged 90 dying in the second year (between ages 91 and 92) is the probability that he does not die in the first year multiplied by the probability that he does die in the second year. From the numbers in the second column of the table, this is

$$(1 - 0.168352) \times 0.185486 = 0.154259$$

Similarly, the probability that he dies in the third year (between ages 92 and 93) is

$$(1 - 0.168352) \times (1 - 0.185486) \times 0.203817 = 0.138063$$

Assuming that death occurs on average halfway though a year, the life expectancy of a man aged 90 is

$$0.5 \times 0.168352 + 1.5 \times 0.154259 + 2.5 \times 0.138063 + \ldots$$

Example 2.1

Assume that interest rates for all maturities arc 4% per annum (with semiannual compounding) and premiums are paid once a year at the beginning of the year. What is an insurance company's break-even premium for $100,000 of term life insurance for a man of average health aged 90? If the term insurance lasts one year, the expected payout is 0.168352 × 100,000 or $16,835. Assume that the payout occurs halfway through the year. (This is likely to be approximately true on average.) The premium is $16,835 discounted for six months. This is 16,835/1.02 or $16,505.

Suppose next that the term insurance lasts two years. In this case, the present value of expected payout in the first year is $16,505 as before. The probability that the policyholder dies during the second year is (1 − 0.168352) × 0.185486 = 0.154259 so that there is also an expected payout of 0.154259 × 100,000 or $15,426 during the second year. Assuming this happens at time 18 months, the present value of the payout is 15,426/(1.02³) or $14,536. The total present value of payouts is 16,505 + 14,536 or $31,041.

Consider next the premium payments. The first premium is required at time zero, so we are certain that this will be paid. The probability of the second premium payment being made at the beginning of the second year is the probability that the man does not die during the first year. This is 1 − 0.168352 = 0.831648. When the premium is X dollars per year, the present value of the premium payments is

$$X + \frac{0.831648X}{(1.02)^2} = 1.799354X$$

The break-even annual premium is given by the value of X that equates the present value of the expected premium payments to the present value of the expected payout. This is the value of X that solves

$$1.799354X = 31{,}041$$

or X = 17,251. The break-even premium payment is therefore $17,251.

LONGEVITY AND MORTALITY RISK

Longevity risk is the risk that advances in medical sciences and lifestyle changes will lead to people living longer. Increases in longevity adversely affect the profitability of most types of annuity contracts (because the annuity has to be paid for longer), but increases the profitability of most life insurance contracts (because the final payout is either delayed or, in the case of term insurance, less likely to happen). Life expectancy has been steadily increasing in most parts of the world. Average life expectancy of a child born in the United States in 2009 is estimated to be

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about 20 years higher than for a child born in 1929. Life expectancy varies from country to country.

Mortality risk is the risk that wars, epidemics such as AIDS, or pandemics such as Spanish flu will lead to people living not as long as expected. This adversely affects the payouts on most types of life insurance contracts (because the insured amount has to be paid earlier than expected), but should increase the profitability of annuity contracts (because the annuity is not paid out for as long). In calculating the impact of mortality risk, it is important to consider the age groups within the population that are likely to be most affected by a particular event.

To some extent, the longevity and mortality risks in the annuity business of a life insurance company offset those in its regular life insurance contracts. Actuaries must carefully assess the insurance company's net exposure under different scenarios. If the exposure is unacceptable, they may decide to enter into reinsurance contracts for some of the risks. Reinsurance is discussed later in this chapter.

Longevity Derivatives

A longevity derivative provides payoffs that are potentially attractive to insurance companies when they are concerned about their longevity exposure on annuity contracts and to pension funds. A typical contract is a *longevity bond*, also known as a *survivor bond*, which first traded in the late 1990s. A population group is defined and the coupon on the bond at any given time is defined as being proportional to the number of individuals in the population that are still alive.

Who will sell such bonds to insurance companies and pension funds? The answer is some speculators find the bonds attractive because they have very little systematic risk. The bond payments depend on how long people live and this is largely uncorrelated with returns from the market.

PROPERTY-CASUALTY INSURANCE

Property-casualty insurance can be subdivided into property insurance and casualty insurance. Property insurance provides protection against loss of or damage to property (from fire, theft, water damage, etc.). Casualty insurance provides protection against legal liability exposures (from, for example, injuries caused to third parties). Casualty insurance might more accurately be referred to as liability insurance. Sometimes both types of insurance are included in a single policy. For example, a home owner might buy insurance that provides protection against various types of loss such as property damage and theft as well as legal liabilities if others are injured while on the property. Similarly, car insurance typically provides protection against theft of, or damage to, one's own vehicle as well as protection against claims brought by others.

Typically, property-casualty policies are renewed from year to year and the insurance company will change the premium if its assessment of the expected payout changes. (This is different from life insurance, where premiums tend to remain the same for the life of the policy.) Because property-casualty insurance companies get involved in many different types of insurance there is some natural risk diversification. Also, for some risks, the "law of large numbers" applies. For example, if an insurance company has written policies protecting 250,000 home owners against losses from theft and fire damage, the expected payout can be predicted reasonably accurately. This is because the policies provide protection against a large number of (almost) independent events. (Of course, there are liable to be trends through time in the number of losses and *size* of losses, and the insurance company should keep track of these trends in determining year-to-year changes in the premiums.)

Property damage arising from natural disasters such as hurricanes give rise to payouts for an insurance company that are much less easy to predict. For example, Hurricane Katrina in the United States in the summer of 2005 and a heavy storm in northwest Europe in January 2007 that measured 12 on the Beaufort scale proved to be very expensive. These are termed *catastrophic risks*. The problem with them is that the claims made by different policyholders are not independent. Either a hurricane happens in a year and the insurance company has to deal with a large number of claims for hurricane-related damage or there is no hurricane in the year and therefore no claims are made. Most large insurers have models based on geographical, seismographical, and meteorological information to estimate the probabilities of catastrophes and the losses resulting therefrom. This provides a basis for setting premiums, but it does not alter the "all-or-nothing" nature of these risks for insurance companies.

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Liability insurance, like catastrophe insurance, gives rise to total payouts that vary from year to year and are difficult to predict. For example, claims arising from asbestos-related damages to workers' health have proved very expensive for insurance companies in the United States. A feature of liability insurance is what is known as *long-tail risk.* This is the possibility of claims being made several years after the insured period is over. In the case of asbestos, for example, the health risks were not realized until some time after exposure. As a result, the claims, when they were made, were under policies that had been in force several years previously. This creates a complication for actuaries and accountants. They cannot close the books soon after the end of each year and calculate a profit or loss. They must allow for the cost of claims that have not yet been made, but may be made some time in the future.

CAT Bonds

The derivatives market has come up with a number of products for hedging catastrophic risk. The most popular is a catastrophe (CAT) bond. This is a bond issued by a subsidiary of an insurance company that pays a higher-than-normal interest rate. In exchange for the extra interest, the holder of the bond agrees to cover payouts on a particular type of catastrophic risk that are in a certain range. Depending on the terms of the CAT bond, the interest or principal (or both) can be used to meet claims.

Suppose an insurance company has a $70 million exposure to California earthquake losses and wants protection for losses over $40 million. The insurance company could issue CAT bonds with a total principal of $30 million. In the event that the insurance company's California earthquake losses exceeded $40 million, bondholders would lose some or all of their principal. As an alternative, the insurance company could cover the same losses by making a much bigger bond issue where only the bondholders' interest is at risk. Yet another alternative is to make three separate bond issues covering losses in the range $40 to $50 million, $50 to $60 million, and $60 to $70 million, respectively.

CAT bonds typically give a high probability of an above-normal rate of interest and a low-probability of a high loss. Why would investors be interested in such instruments? The answer is that the return on CAT bonds, like the longevity bonds considered earlier, have no statistically significant correlations with market returns.[2] CAT bonds are therefore an attractive addition to an investor's portfolio. Their total risk can be completely diversified away in a large portfolio. If a CAT bond's expected return is greater than the risk-free interest rate (and typically it is), it has the potential to improve risk-return trade-offs.

Ratios Calculated by Property-Casualty Insurers

Insurance companies calculate a *loss ratio* for different types of insurance. This is the ratio of payouts made to premiums earned in a year. Loss ratios are typically in the 60% to 80% range. Statistics published by A. M. Best show that loss ratios in the United States have tended to increase through time. The *expense ratio* for an insurance company is the ratio of expenses to premiums earned in a year. The two major sources of expenses are loss adjustment expenses and selling expenses. Loss adjustment expenses are those expenses related to determining the validity of a claim and how much the policyholder should be paid. Selling expenses include the commissions paid to brokers and other expenses concerned with the acquisition of business. Expense ratios in the United States are typically in the 25% to 30% range and have tended to decrease through time.

The *combined ratio* is the sum of the loss ratio and the expense ratio. Suppose that for a particular category of policies in a particular year the loss ratio is 75% and the expense ratio is 30%. The combined ratio is then 105%. Sometimes a small dividend is paid to policyholders. Suppose that this is 1% of premiums. When this is taken into account we obtain what is referred to as the *combined ratio after dividends.* This is 106% in our example. This number suggests that the insurance company has lost 6% before tax on the policies being considered. In fact, this may not be the case. Premiums are generally paid by policyholders at the beginning of a year and payouts on claims are made during the year, or after the end of the year. The

[2] See R. H. Litzenberger, D. R. Beaglehole, and C. E. Reynolds, "Assessing Catastrophe Reinsurance-Linked Securities as a New Asset Class," *Journal of Portfolio Management* (Winter 1996): 76–86.

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TABLE 2-2 Example Showing Calculation of Operating Ratio for a Property-Casualty Insurance Company

Loss ratio	75%
Expense ratio	30%
Combined ratio	105%
Dividends	1%
Combined ratio after dividends	106%
Investment income	(9%)
Operating ratio	97%

insurance company is therefore able to earn interest on the premiums during the time that elapses between the receipt of premiums and payouts. Suppose that, in our example, investment income is 9% of premiums received. When the investment income is taken into account, a ratio of 106 − 9 = 97% is obtained. This is referred to as the *operating ratio.* Table 2-2 summarizes this example.

HEALTH INSURANCE

Health insurance has some of the attributes of property-casualty insurance and some of the attributes of life insurance. It is sometimes considered to be a totally separate category of insurance. The extent to which health care is provided by the government varies from country to country. In the United States publicly funded health care has traditionally been limited and health insurance has therefore been an important consideration for most people. Canada is at the other extreme; nearly all health care needs are provided by a publicly funded system. Doctors are not allowed to offer most services privately. The main role of health insurance in Canada is to cover prescription costs and dental care, which are not funded publicly. In most other countries, there is a mixture of public and private health care. The United Kingdom, for example, has a publicly funded health care system, but some individuals buy insurance to have access to a private system that operates side by side with the public system. (The main advantage of private health insurance is a reduction in waiting times for routine elective surgery.)

In 2010, President Obama signed into law the Patient Protection and Affordable Care Act in an attempt to reform health care in the United States and increase the number of people with medical coverage. The eligibility for Medicaid (a program for low income individuals) was expanded and subsidies were provided for low and middle income families to help them buy insurance. The act prevents health insurers from taking pre-existing medical conditions into account and requires employers to provide coverage to their employees or pay additional taxes. One difference between the United States and many other countries continues to be that health insurance is largely provided by the private rather than the public sector.

In health insurance, as in other forms of insurance, the policyholder makes regular premium payments and payouts are triggered by events. Examples of such events are the policyholder needing an examination by a doctor, the policyholder requiring treatment at a hospital, and the policyholder requiring prescription medication. Typically the premiums increase because of overall increases in the costs of providing health care. However, they usually cannot increase because the health of the policyholder deteriorates. It is interesting to compare health insurance with auto insurance and life insurance in this respect. An auto insurance premium can increase (and usually does) if the policyholder's driving record indicates that expected payouts have increased and if the costs of repairs to automobiles have increased. Life insurance premiums do not increase—even if the policyholder is diagnosed with a health problem that significantly reduces life expectancy. Health insurance premiums are like life insurance premiums in that changes to the insurance company's assessment of the risk of a payout do not lead to an increase in premiums. However, it is like auto insurance in that increases in the overall costs of meeting claims do lead to premium increases.

Of course, when a policy is first issued, an insurance company does its best to determine the risks it is taking on. In the case of life insurance, questions concerning the policyholder's health have to be answered, pre-existing medical conditions have to be declared, and physical examinations may be required. In the case of auto insurance, the policyholder's driving record is investigated. In both of these cases, insurance can be refused. In the case of health insurance, legislation sometimes determines the circumstances under which insurance can be refused. As indicated earlier, the Patient Protection and Affordable Health Care Act makes it very difficult for insurance companies in the United States to refuse applications because of pre-existing medical conditions.

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Health insurance is often provided by the *group health insurance plans* of employers. These plans typically cover the employee and the employee's family. The cost of the health insurance is sometimes split between the employer and employee. The expenses that are covered vary from plan to plan. In the United States, most plans cover basic medical needs such as medical check-ups, physicals, treatments for common disorders, surgery, and hospital stays. Pregnancy costs may or may not be covered. Procedures such as cosmetic surgery are usually not covered.

MORAL HAZARD AND ADVERSE SELECTION

We now consider two key risks facing insurance companies: moral hazard and adverse selection.

Moral Hazard

Moral hazard is the risk that the existence of insurance will cause the policyholder to behave differently than he or she would without the insurance. This different behavior increases the risks and the expected payouts of the insurance company. Three examples of moral hazard are:

1. A car owner buys insurance to protect against the car being stolen. As a result of the insurance, he or she becomes less likely to lock the car.
2. An individual purchases health insurance. As a result of the existence of the policy, more health care is demanded than previously.
3. As a result of a government-sponsored deposit insurance plan, a bank takes more risks because it knows that it is less likely to lose depositors because of this strategy. (This was discussed in Chapter 1)

Moral hazard is not a big problem in life insurance. Insurance companies have traditionally dealt with moral hazard in property-casualty and health insurance in a number of ways. Typically there is a *deductible.* This means that the policyholder is responsible for bearing the first part of any loss. Sometimes there is a *co-insurance provision* in a policy. The insurance company then pays a predetermined percentage (less than 100%) of losses in excess of the deductible. In addition there is nearly always a *policy limit* (i.e., an upper limit to the payout). The effect of these provisions is to align the interests of the policyholder more closely with those of the insurance company.

Adverse Selection

Adverse selection is the phrase used to describe the problems an insurance company has when it cannot distinguish between good and bad risks. It offers the same price to everyone and inadvertently attracts more of the bad risks. If an insurance company is not able to distinguish good drivers from bad drivers and offers the same auto insurance premium to both, it is likely to attract more bad drivers. If it is not able to distinguish healthy from unhealthy people and offers the same life insurance premiums to both, it is likely to attract more unhealthy people.

To lessen the impact of adverse selection, an insurance company tries to find out as much as possible about the policyholder before committing itself. Before offering life insurance, it often requires the policyholder to undergo a physical examination by an approved doctor. Before offering auto insurance to an individual, it will try to obtain as much information as possible about the individual's driving record. In the case of auto insurance, it will continue to collect information on the driver's risk (number of accidents, number of speeding tickets, etc.) and make year-to-year changes to the premium to reflect this.

Adverse selection can never be completely overcome. It is interesting that, in spite of the physical examinations that are required, individuals buying life insurance tend to die earlier than mortality tables would suggest. But individuals who purchase annuities tend to live longer than mortality tables would suggest.

REINSURANCE

Reinsurance is an important way in which an insurance company can protect itself against large losses by entering into contracts with another insurance company. For a fee, the second insurance company agrees to be responsible for some of the risks that have been insured by the first company. Reinsurance allows insurance companies to write more policies than they would otherwise be able to. Some of the counterparties in reinsurance contracts are other insurance companies or rich private individuals; others are companies that specialize in reinsurance such as Swiss Re and Warren Buffett's company, Berkshire Hathaway.

Reinsurance contracts can take a number of forms. Suppose that an insurance company has an exposure of

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$100 million to hurricanes in Florida and wants to limit this to $50 million. One alternative is to enter into annual reinsurance contracts that cover on a pro rata basis 50% of its exposure. (The reinsurer would then probably receive 50% of the premiums.) If hurricane claims in a particular year total $70 million, the costs to the insurance company would be only 0.5 × $70 or $35 million, and the reinsurance company would pay the other $35 million.

Another more popular alternative, involving lower reinsurance premiums, is to buy a series of reinsurance contracts covering what are known as *excess cost layers*. The first layer might provide indemnification for losses between $50 million and $60 million, the next layer might cover losses between $60 million and $70 million, and so on. Each reinsurance contract is known as an *excess-of-loss* reinsurance contract.

CAPITAL REQUIREMENTS

The balance sheets for life insurance and property-casualty insurance companies are different because the risks taken and reserves that must be set aside for future payouts are different.

Life Insurance Companies

Table 2-3 shows an abbreviated balance sheet for a life insurance company. Most of the life insurance company's investments are in corporate bonds. The insurance company tries to match the maturity of its assets with the maturity of liabilities. However, it takes on credit risk because the default rate on the bonds may be higher than expected.

TABLE 2-3 Abbreviated Balance Sheet for Life Insurance Company

Assets		Liabilities and Net Worth	
Investments	90	Policy reserves	80
Other assets	10	Subordinated long-term debt	10
		Equity capital	10
Total	**100**	**Total**	**100**

Unlike a bank, an insurance company has exposure on the liability side of the balance sheet as well as on the asset side. The policy reserves (80% of assets in this case) are estimates (usually conservative) of actuaries for the present value of payouts on the policies that have been written. The estimates may prove to be low if the holders of life insurance policies die earlier than expected or the holders of annuity contracts live longer than expected. The 10% equity on the balance sheet includes the original equity contributed and retained earnings and provides a cushion. If payouts are greater than loss reserves by an amount equal to 5% of assets, equity will decline, but the life insurance company will survive.

Property-Casualty Insurance Companies

Table 2-4 shows an abbreviated balance sheet for a property-casualty life insurance company. A key difference between Table 2-3 and Table 2-4 is that the equity in Table 2-4 is much higher. This reflects the differences in the risks taken by the two sorts of insurance companies. The payouts for a property-casualty company are much less easy to predict than those for a life insurance company. Who knows when a hurricane will hit Miami or how large payouts will be for the next asbestos-like liability problem? The unearned premiums item on the liability side represents premiums that have been received, but apply to future time periods. If a policyholder pays $2,500 for house insurance on June 30 of a year, only $1,250 has been earned by December 31 of the year. The investments in Table 2-4 consist largely of liquid bonds with shorter maturities than the bonds in Table 2-3.

TABLE 2-4 Abbreviated Balance Sheet for Property-Casualty Insurance Company

Assets		Liabilities and Net Worth	
Investments	90	Policy reserves	45
Other assets	10	Unearned premiums	15
		Subordinated long-term debt	10
		Equity capital	30
Total	**100**	**Total**	**100**

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THE RISKS FACING INSURANCE COMPANIES

The most obvious risk for an insurance company is that the policy reserves are not sufficient to meet the claims of policyholders. Although the calculations of actuaries are usually fairly conservative, there is always the chance that payouts much higher than anticipated will be required. Insurance companies also face risks concerned with the performance of their investments. Many of these investments are in corporate bonds. If defaults on corporate bonds are above average, the profitability of the insurance company will suffer. It is important that an insurance company's bond portfolio be diversified by business sector and geographical region. An insurance company also needs to monitor the liquidity risks associated with its investments. Illiquid bonds (e.g., those the insurance company might buy in a private placement) tend to provide higher yields than bonds that are publicly owned and actively traded. However, they cannot be as readily converted into cash to meet unexpectedly high claims. Insurance companies enter into transactions with banks and reinsurance companies. This exposes them to credit risk. Like banks, insurance companies are also exposed to operational risks and business risks.

Regulators specify minimum capital requirements for an insurance company to provide a cushion against losses. Insurance companies, like banks, have also developed their own procedures for calculating economic capital. This is their own internal estimate of required capital.

REGULATION

The ways in which insurance companies are regulated in the United States and Europe are quite different.

United States

In the United States, the McCarran-Ferguson Act of 1945 confirmed that insurance companies are regulated at the state level rather than the federal level. (Banks, by contrast, are regulated at the federal level.) State regulators are concerned with the solvency of insurance companies and their ability to satisfy policyholders' claims. They are also concerned with business conduct (i.e., how premiums are set, advertising, contract terms, the licensing of insurance agents and brokers, and so on).

The National Association of Insurance Commissioners (NAIC) is an organization consisting of the chief insurance regulatory officials from all 50 states. It provides a national forum for insurance regulators to discuss common issues and interests. It also provides some services to state regulatory commissions. For example, it provides statistics on the loss ratios of property-casualty insurers. This helps state regulators identify those insurers for which the ratios are outside normal ranges.

Insurance companies are required to file detailed annual financial statements with state regulators, and the state regulators conduct periodic on-site reviews. Capital requirements are determined by regulators using risk-based capital standards determined by NAIC. These capital levels reflect the risk that policy reserves are inadequate, that counterparties in transactions default, and that the return from investments is less than expected.

The policyholder is protected against an insurance company becoming insolvent (and therefore unable to make payouts on claims) by insurance guaranty associations. An insurer is required to be a member of the guaranty association in a state as a condition of being licensed to conduct business in the state. When there is an insolvency by another insurance company operating in the state, each insurance company operating in the state has to contribute an amount to the state guaranty fund that is dependent on the premium income it collects in the state. The fund is used to pay the small policyholders of the insolvent insurance company. (The definition of a small policyholder varies from state to state.) There may be a cap on the amount the insurance company has to contribute to the state guaranty fund in a year. This can lead to the policyholder having to wait several years before the guaranty fund is in a position to make a full payout on its claims. In the case of life insurance, where policies last for many years, the policyholders of insolvent companies are usually taken over by other insurance companies. However, there may be some change to the terms of the policy so that the policyholder is somewhat worse off than before.

The guaranty system for insurance companies in the United States is therefore different from that for banks. In the case of banks, there is a permanent fund created from premiums paid by banks to the FDIC to protect depositors. In the case of insurance companies, there is no

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permanent fund. Insurance companies have to make contributions after an insolvency has occurred. An exception to this is property-casualty companies in New York State, where a permanent fund does exist.

Regulating insurance companies at the state level is unsatisfactory in some respects. Regulations are not uniform across the different states. A large insurance company that operates throughout the United States has to deal with a large number of different regulatory authorities. Some insurance companies trade derivatives in the same way as banks, but are not subject to the same regulations as banks. This can create problems. In 2008, it transpired that a large insurance company, American International Group (AIG), had incurred huge losses trading credit derivatives and had to be bailed out by the federal government.

The Dodd-Frank Act of 2010 set up the Federal Insurance Office (FIO), which is housed in the Department of the Treasury. It is tasked with monitoring the insurance industry and identifying gaps in regulation. It can recommend to the Financial Stability Oversight Council that a large insurance company (such as AIG) be designated as a nonbank financial company supervised by the Federal Reserve. It also liaises with regulators in other parts of the world (particularly, those in the European Union) to foster the convergence of regulatory standards. The Dodd-Frank Act required the FIO to "conduct a study and submit a report to Congress on how to modernize and improve the system of insurance regulation in the United States." The FIO submitted its report in December 2013.[3] It identified changes necessary to improve the U.S. system of insurance regulation. It seems likely that the United States will either (a) move to a system where regulations are determined federally and administered at the state level or (b) move to a system where regulations are set federally and administered federally.

Europe

In the European Union, insurance companies are regulated centrally. This means that in theory the same regulatory framework applies to insurance companies throughout all member countries. The framework that has existed since the 1970s is known as Solvency I. It was heavily influenced by research carried out by Professor Campagne from the Netherlands who showed that, with a capital equal to 4% of policy provisions, life insurance companies have a 95% chance of surviving. Investment risks are not explicitly considered by Solvency I.

A number of countries, such as the UK, the Netherlands, and Switzerland, have developed their own plans to overcome some of the weaknesses in Solvency I. The European Union is working on Solvency II, which assigns capital for a wider set of risks than Solvency I and is expected to be implemented in 2016.

PENSION PLANS

Pension plans are set up by companies for their employees. Typically, contributions are made to a pension plan by both the employee and the employer while the employee is working. When the employee retires, he or she receives a pension until death. A pension fund therefore involves the creation of a lifetime annuity from regular contributions and has similarities to some of the products offered by life insurance companies. There are two types of pension plans: defined benefit and defined contribution.

In a *defined benefit plan,* the pension that the employee will receive on retirement is defined by the plan. Typically it is calculated by a formula that is based on the number of years of employment and the employee's salary. For example, the pension per year might equal the employee's average earnings per year during the last three years of employment multiplied by the number of years of employment multiplied by 2%. The employee's spouse may continue to receive a (usually reduced) pension if the employee dies before the spouse. In the event of the employee's death while still employed, a lump sum is often payable to dependents and a monthly income may be payable to a spouse or dependent children. Sometimes pensions are adjusted for inflation. This is known as indexation. For example, the indexation in a defined benefit plan might lead to pensions being increased each year by 75% of the increase in the consumer price index. Pension plans that are sponsored by governments (such as Social Security in the United States) are similar to defined benefit plans in that they require regular contributions up to a certain age and then provide lifetime pensions.

[3] See "How to Modernize and Improve the System Insurance Regulation in the United States," Federal Insurance Office, December 2013.

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In a *defined contribution plan* the employer and employee contributions are invested on behalf of the employee. When employees retire, there are typically a number of options open to them. The amount to which the contributions have grown can be converted to a lifetime annuity. In some cases, the employee can opt to receive a lump sum instead of an annuity.

The key difference between a defined contribution and a defined benefit plan is that, in the former, the funds are identified with individual employees. An account is set up for each employee and the pension is calculated only from the funds contributed to that account. By contrast, in a defined benefit plan, all contributions are pooled and payments to retirees are made out of the pool. In the United States, a 401(k) plan is a form of defined contribution plan where the employee elects to have some portion of his or her income directed to the plan (with possibly some employer matching) and can choose between a number of investment alternatives (e.g., stocks, bonds, and money market instruments).

An important aspect of both defined benefit and defined contribution plans is the deferral of taxes. No taxes are payable on money contributed to the plan by the employee and contributions by a company are deductible. Taxes are payable only when pension income is received (and at this time the employee may have a relatively low marginal tax rate).

Defined contribution plans involve very little risk for employers. If the performance of the plan's investments is less than anticipated, the employee bears the cost. By contrast, defined benefit plans impose significant risks on employers because they are ultimately responsible for paying the promised benefits. Let us suppose that the assets of a defined benefit plan total $100 million and that actuaries calculate the present value of the obligations to be $120 million. The plan is $20 million underfunded and the employer is required to make up the shortfall (usually over a number of years). The risks posed by defined benefit plans have led some companies to convert defined benefit plans to defined contribution plans.

Estimating the present value of the liabilities in defined benefit plans is not easy. An important issue is the discount rate used. The higher the discount rate, the lower the present value of the pension plan liabilities. It used to be common to use the average rate of return on the assets of the pension plan as the discount rate. This encourages the pension plan to invest in equities because the average return on equities is higher than the average return on bonds, making the value of the liabilities look low. Accounting standards now recognize that the liabilities of pension plans are obligations similar to bonds and require the liabilities of the pension plans of private companies to be discounted at AA-rated bond yields. The difference between the value of the assets of a defined benefit plan and that of its liabilities must be recorded as an asset or liability on the balance sheet of the company. Thus, if a company's defined benefit plan is underfunded, the company's shareholder equity is reduced. A perfect storm is created when the assets of a defined benefits pension plan decline sharply in value and the discount rate for its liabilities decreases sharply (see Box 2-2).

Are Defined Benefit Plans Viable?

A typical defined benefit plan provides the employee with about 70% of final salary as a pension and includes some indexation for inflation. What percentage of the employee's income during his or her working life should be set aside for providing the pension? The answer depends on assumptions about interest rates, how fast the employee's income rises during the employee's working life, and so on. But, if an insurance company were asked to provide a

BOX 2-2 A Perfect Storm

During the period from December 31, 1999 to December 31, 2002, the S&P 500 declined by about 40% from 1469.25 to 879.82 and 20-year Treasury rates in the United States declined by 200 basis points from 6.83% to 4.83%. The impact of the first of these events was that the market value of the assets of defined benefit pension plans declined sharply. The impact of the second of the two events was that the discount rate used by defined benefit plans for their liabilities decreased so that the fair value of the liabilities calculated by actuaries increased. This created a "perfect storm" for the pension plans. Many funds that had been overfunded became underfunded. Funds that had been slightly underfunded became much more seriously underfunded.

When a company has a defined benefit plan, the value of its equity is adjusted to reflect the amount by which the plan is overfunded or underfunded. It is not surprising that many companies have tried to replace defined benefit pension plans with defined contribution plans to avoid the risk of equity being eroded by a perfect storm.

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quote for the sort of defined benefit plan we are considering, the required contribution rate would be about 25% of income each year. The insurance company would invest the premiums in corporate bonds (in the same way that it does the premiums for life insurance and annuity contracts) because this provides the best way of matching the investment income with the payouts.

The contributions to defined benefit plans (employer plus employee) are much less than 25% of income. In a typical defined benefit plan, the employer and employee each contribute around 5%. The total contribution is therefore only 40% of what an insurance actuary would calculate the required premium to be. It is therefore not surprising that many pension plans are underfunded.

Unlike insurance companies, pension funds choose to invest a significant proportion of their assets in equities. (A typical portfolio mix for a pension plan is 60% equity and 40% debt.) By investing in equities, the pension fund is creating a situation where there is some chance that the pension plan will be fully funded. But there is also some chance of severe underfunding. If equity markets do well, as they have done from 1960 to 2000 in many parts of the world, defined benefit plans find they can afford their liabilities. But if equity markets perform badly, there are likely to be problems.

This raises an interesting question: Who is responsible for underfunding in defined benefit plans? In the first instance, it is the company's shareholders that bear the cost. If the company declares bankruptcy, the cost may be borne by the government via insurance that is offered.[4] In either case there is a transfer of wealth to retirees from the next generation.

Many people argue that wealth transfers from one generation to another are not acceptable. A 25% contribution rate to pension plans is probably not feasible. If defined benefit plans are to continue, there must be modifications to the terms of the plans so that there is some risk sharing between retirees and the next generation. If equity markets perform badly during their working life, retirees must be prepared to accept a lower pension and receive only modest help from the next generation. If equity markets perform well, retirees can receive a full pension and some of the benefits can be passed on to the next generation.

Longevity risk is a major concern for pension plans. We mentioned earlier that life expectancy increased by about 20 years between 1929 and 2009. If this trend continues and life expectancy increases by a further five years by 2029, the underfunding problems of defined benefit plans (both those administered by companies and those administered by national governments) will become more severe. It is not surprising that, in many jurisdictions, individuals have the right to work past the normal retirement age. This helps solve the problems faced by defined benefit pension plans. An individual who retires at 70 rather than 65 makes an extra five years of pension contributions and the period of time for which the pension is received is shorter by five years.

SUMMARY

There are two main types of insurance companies: life and property-casualty. Life insurance companies offer a number of products that provide a payoff when the policyholder dies. Term life insurance provides a payoff only if the policyholder dies during a certain period. Whole life insurance provides a payoff on the death of the insured, regardless of when this is. There is a savings element to whole life insurance. Typically, the portion of the premium not required to meet expected payouts in the early years of the policy is invested, and this is used to finance expected payouts in later years. Whole life insurance policies usually give rise to tax benefits, because the present value of the tax paid is less than it would be if the investor had chosen to invest funds directly rather than through the insurance policy.

Life insurance companies also offer annuity contracts. These are contracts that, in return for a lump sum payment, provide the policyholder with an annual income from a certain date for the rest of his or her life. Mortality tables provide important information for the valuation of the life insurance contracts and annuities. However, actuaries must consider (a) longevity risk (the possibility that people will live longer than expected) and (b) mortality risk (the possibility that epidemics such as AIDS or Spanish flu will reduce life expectancy for some segments of the population).

Property-casualty insurance is concerned with providing protection against a loss of, or damage to, property. It also

[4] For example, in the United States, the Pension Benefit Guaranty Corporation (PBGC) insures private defined benefit plans. If the premiums the PBGC receives from plans are not sufficient to meet claims, presumably the government would have to step in.

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protects individuals and companies from legal liabilities. The most difficult payouts to predict are those where the same event is liable to trigger claims by many policyholders at about the same time. Examples of such events are hurricanes or earthquakes.

Health insurance has some of the features of life insurance and some of the features of property-casualty insurance. Health insurance premiums are like life insurance premiums in that changes to the company's assessment of the risk of payouts do not lead to an increase in premiums. However, it is like property-casualty insurance in that increases in the overall costs of providing health care can lead to increases on premiums.

Two key risks in insurance are moral hazard and adverse selection. Moral hazard is the risk that the behavior of an individual or corporation with an insurance contract will be different from the behavior without the insurance contract. Adverse selection is the risk that the individuals and companies who buy a certain type of policy are those for which expected payouts are relatively high. Insurance companies take steps to reduce these two types of risk, but they cannot eliminate them altogether.

Insurance companies are different from banks in that their liabilities as well as their assets are subject to risk. A property-casualty insurance company must typically keep more equity capital, as a percent of total assets, than a life insurance company. In the United States, insurance companies are different from banks in that they are regulated at the state level rather than at the federal level. In Europe, insurance companies are regulated by the European Union and by national governments. The European Union is developing a new set of capital requirements known as Solvency II.

There are two types of pension plans: defined benefit plans and defined contribution plans. Defined contribution plans are straightforward. Contributions made by an employee and contributions made by the company on behalf of the employee are kept in a separate account, invested on behalf of the employee, and converted into a lifetime annuity when the employee retires. In a defined benefit plan, contributions from all employees and the company are pooled and invested. Retirees receive a pension that is based on the salary they earned while working. The viability of defined benefit plans is questionable. Many are underfunded and need superior returns from equity markets to pay promised pensions to both current retirees and future retirees.

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Mutual Funds and Hedge Funds

3

Learning Objectives

After completing this reading you should be able to:

- Differentiate among open-end mutual funds, closed-end mutual funds, and exchange-traded funds (ETFs).
- Calculate the net asset value (NAV) of an open-end mutual fund.
- Explain the key differences between hedge funds and mutual funds.
- Calculate the return on a hedge fund investment and explain the incentive fee structure of a hedge fund including the terms hurdle rate, high-water mark, and clawback.
- Describe various hedge fund strategies, including long/short equity, dedicated short, distressed securities, merger arbitrage, convertible arbitrage, fixed income arbitrage, emerging markets, global macro, and managed futures, and identify the risks faced by hedge funds.
- Describe hedge fund performance and explain the effect of measurement biases on performance measurement.

Excerpt is from Chapter 4 of Risk Management and Financial Institutions, 4th Edition, *by John Hull.*

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Mutual funds and hedge funds invest money on behalf of individuals and companies. The funds from different investors are pooled and investments are chosen by the fund manager in an attempt to meet specified objectives. Mutual funds, which are called "unit trusts" in some countries, serve the needs of relatively small investors, while hedge funds seek to attract funds from wealthy individuals and large investors such as pension funds. Hedge funds are subject to much less regulation than mutual funds. They are free to use a wider range of trading strategies than mutual funds and are usually more secretive about what they do. Mutual funds are required to explain their investment policies in a prospectus that is available to potential investors.

This chapter describes the types of mutual funds and hedge funds that exist. It examines how they are regulated and the fees they charge. It also looks at how successful they have been at producing good returns for investors.

MUTUAL FUNDS

One of the attractions of mutual funds for the small investor is the diversification opportunities they offer. Diversification improves an investor's risk-return trade-off. However, it can be difficult for a small investor to hold enough stocks to be well diversified. In addition, maintaining a well-diversified portfolio can lead to high transaction costs. A mutual fund provides a way in which the resources of many small investors are pooled so that the benefits of diversification are realized at a relatively low cost.

Mutual funds have grown very fast since the Second World War. Table 3-1 shows estimates of the assets managed by mutual funds in the United States since 1940. These assets were over $15 trillion by 2014. About 46% of U.S. households own mutual funds. Some mutual funds are offered by firms that specialize in asset management, such as Fidelity. Others are offered by banks such as JPMorgan Chase. Some insurance companies also offer mutual funds. For example, in 2001 the large U.S. insurance company, State Farm, began offering 10 mutual funds throughout the United States. They can be purchased over the Internet or by phone or through State Farm agents.

TABLE 3-1 Growth of Assets of Mutual Funds In the United States

Year	Assets ($ billions)
1940	0.5
1960	17.0
1980	134.8
2000	6,964.6
2014 (April)	15,196.2

Source: Investment Company Institute.

Money market mutual funds invest in interest-bearing instruments, such as Treasury bills, commercial paper, and bankers' acceptances, with a life of less than one year. They are an alternative to interest-bearing bank accounts and usually provide a higher rate of interest because they are not insured by a government agency. Some money market funds offer check writing facilities similar to banks. Money market fund investors are typically risk-averse and do not expect to lose any of the funds invested. In other words, investors expect a positive return after management fees.[1] In normal market conditions this is what they get. But occasionally the return is negative so that some principal is lost. This is known as "breaking the buck" because a $1 investment is then worth less than $1. After Lehman Brothers defaulted in September 2008, the oldest money fund in the United States, Reserve Primary Fund, broke the buck because it had to write off short-term debt issued by Lehman. To avoid a run on money market funds (which would have meant healthy companies had no buyers for their commercial paper), a government-backed guaranty program was introduced. It lasted for about a year.

There are three main types of long-term funds:

1. Bond funds that invest in fixed income securities with a life of more than one year.
2. Equity funds that invest in common and preferred stock.
3. Hybrid funds that invest in stocks, bonds, and other securities.

Equity mutual funds are by far the most popular.

An investor in a long-term mutual fund owns a certain number of shares in the fund. The most common type

[1] Stable value funds are a popular alternative to money market funds. They typically invest in bonds and similar instruments with lives of up to five years. Banks and other companies provide (for a price) insurance guaranteeing that the return will not be negative.

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of mutual fund is an *open-end fund*. This means that the total number of shares outstanding goes up as investors buy more shares and down as shares are redeemed. Mutual funds are valued at 4 P.M. each day. This involves the mutual fund manager calculating the market value of each asset in the portfolio so that the total value of the fund is determined. This total value is divided by the number of shares outstanding to obtain the value of each share. The latter is referred to as the *net asset value* (NAV) of the fund. Shares in the fund can be bought from the fund or sold back to the fund at any time. When an investor issues instructions to buy or sell shares, it is the next-calculated NAV that applies to the transaction. For example, if an investor decides to buy at 2 P.M. on a particular business day, the NAV at 4 P.M. on that day determines the amount paid by the investor.

The investor usually pays tax as though he or she owned the securities in which the fund has invested. Thus, when the fund receives a dividend, an investor in the fund has to pay tax on the investor's share of the dividend, even if the dividend is reinvested in the fund for the investor. When the fund sells securities, the investor is deemed to have realized an immediate capital gain or loss, even if the investor has not sold any of his or her shares in the fund. Suppose the investor buys shares at $100 and the trading by the fund leads to a capital gain of $20 per share in the first tax year and a capital loss of $25 per share in the second tax year. The investor has to declare a capital gain of $20 in the first year and a loss of $25 in the second year. When the investor sells the shares, there is also a capital gain or loss. To avoid double counting, the purchase price of the shares is adjusted to reflect the capital gains and losses that have already accrued to the investor. Thus, if in our example the investor sold shares in the fund during the second year, the purchase price would be assumed to be $120 for the purpose of calculating capital gains or losses on the transaction during the second year; if the investor sold the shares in the fund during the third year, the purchase price would be assumed to be $95 for the purpose of calculating capital gains or losses on the transaction during the third year.

Index Funds

Some funds are designed to track a particular equity index such as the S&P 500 or the FTSE 100. The tracking can most simply be achieved by buying all the shares in the index in amounts that reflect their weight. For example, if IBM has 1% weight in a particular index, 1% of the tracking portfolio for the index would be invested in IBM stock. Another way of achieving tracking is to choose a smaller portfolio of representative shares that has been shown by research to track the chosen portfolio closely. Yet another way is to use index futures.

One of the first index funds was launched in the United States on December 31, 1975, by John Bogle to track the S&P 500. It started with only $11 million of assets and was initially ridiculed as being "un-American" and "Bogle's folly." However, it has been hugely successful and has been renamed the Vanguard 500 Index Fund. The assets under administration reached $100 billion in November 1999.

How accurately do index funds track the index? Two relevant measures are the *tracking error* and the *expense ratio*. The tracking error of a fund can be defined as either the root mean square error of the difference between the fund's return per year and the index return per year or as the standard deviation of this difference.[2] The expense ratio is the fee charged per year, as a percentage of assets, for administering the fund.

Costs

Mutual funds incur a number of different costs. These include management expenses, sales commissions, accounting and other administrative costs, transaction costs on trades, and so on. To recoup these costs, and to make a profit, fees are charged to investors. A *front-end load* is a fee charged when an investor first buys shares in a mutual fund. Not all funds charge this type of fee. Those that do are referred to as front-end loaded. In the United States, front-end loads are restricted to being less than 8.5% of the investment. Some funds charge fees when an investor sells shares. These are referred to as a *back-end load*. Typically the back-end load declines with the length of time the shares in the fund have been held. All funds charge an annual fee. There may be separate fees to cover management expenses, distribution costs, and so on. The *total expense ratio* is the total of the annual fees charged per share divided by the value of the share.

[2] The root mean square error of the difference (square root of the average of the squared differences) is a better measure. The trouble with standard deviation is that it is low when the error is large but fairly constant.

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Khorana et al. (2009) compared the mutual fund fees in 18 different countries.[3] They assume in their analysis that a fund is kept for five years. The total shareholder cost per year is calculated as

$$\text{Total expense ratio} + \frac{\text{Front-end load}}{5} + \frac{\text{Back-end load}}{5}$$

Their results are summarized in Table 3-2. The average fees for equity funds vary from 1.41% in Australia to 3.00% in Canada. Fees for equity funds are on average about 50% higher than for bond funds. Index funds tend to have lower fees than regular funds because no highly paid stock pickers or analysts are required. For some index funds in the United States, fees are as low as 0.15% per year.

TABLE 3-2 Average Total Cost per Year When Mutual Fund Is Held for Five Years (% of Assets)

Country	Bond Funds	Equity Funds
Australia	0.75	1.41
Austria	1.55	2.37
Belgium	1.60	2.27
Canada	1.84	3.00
Denmark	1.91	2.62
Finland	1.76	2.77
France	1.57	2.31
Germany	1.48	2.29
Italy	1.56	2.58
Luxembourg	1.62	2.43
Netherlands	1.73	2.46
Norway	1.77	2.67
Spain	1.58	2.70
Sweden	1.67	2.47
Switzerland	1.61	2.40
United Kingdom	1.73	2.48
United States	1.05	1.53
Average	**1.39**	**2.09**

Source: Khorana, Servaes, and Tufano, "Mutual Fund Fees Around the World," *Review of Financial Studies* 22 (March 2009): 1279–1310.

Closed-end Funds

The funds we have talked about so far are open-end funds. These are by far the most common type of fund. The number of shares outstanding varies from day to day as individuals choose to invest in the fund or redeem their shares. Closed-end funds are like regular corporations and have a fixed number of shares outstanding. The shares of the fund are traded on a stock exchange. For closed-end funds, two NAVs can be calculated. One is the price at which the shares of the fund are trading. The other is the market value of the fund's portfolio divided by the number of shares outstanding. The latter can be referred to as the fair market value. Usually a closed-end fund's share price is less than its fair market value. A number of researchers have investigated the reason for this. Research by Ross (2002) suggests that the fees paid to fund managers provide the explanation.[4]

ETFs

Exchange-traded funds (ETFs) have existed in the United States since 1993 and in Europe since 1999. They often track an index and so are an alternative to an index mutual fund for investors who are comfortable earning a return that is designed to mirror the index. One of the most widely known ETFs, called the Spider, tracks the S&P 500 and trades under the symbol SPY. In a survey of investment professionals conducted in March 2008, 67% called ETFs the most innovative investment vehicle of the previous two decades and 60% reported that ETFs have fundamentally changed the way they construct investment portfolios. In 2008, the SEC in the United States authorized the creation of actively managed ETFs.

[3] See A. Khorana, H. Servaes, and P. Tufano, "Mutual Fund Fees Around the World," *Review of Financial Studies* 22 (March 2009): 1279–1310.

[4] See S. Ross, "Neoclassical Finance, Alternative Finance, and the Closed End Fund Puzzle," *European Financial Management* 8 (2002): 129–137.

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ETFs are created by institutional investors. Typically, an institutional investor deposits a block of securities with the ETF and obtains shares in the ETF (known as *creation units*) in return. Some or all of the shares in the ETF are then traded on a stock exchange. This gives ETFs the characteristics of a closed-end fund rather than an open-end fund. However, a key feature of ETFs is that institutional investors can exchange large blocks of shares in the ETF for the assets underlying the shares at that time. They can give up shares they hold in the ETF and receive the assets or they can deposit new assets and receive new shares. This ensures that there is never any appreciable difference between the price at which shares in the ETF are trading on the stock exchange and their fair market value. This is a key difference between ETFs and closed-end funds and makes ETFs more attractive to investors than closed-end funds.

ETFs have a number of advantages over open-end mutual funds. ETFs can be bought or sold at any time of the day. They can be shorted in the same way that shares in any stock are shorted. ETF holdings are disclosed twice a day, giving investors full knowledge of the assets underlying the fund. Mutual funds by contrast only have to disclose their holdings relatively infrequently. When shares in a mutual fund are sold, managers often have to sell the stocks in which the fund has invested to raise the cash that is paid to the investor. When shares in the ETF are sold, this is not necessary as another investor is providing the cash. This means that transactions costs are saved and there are less unplanned capital gains and losses passed on to shareholders. Finally, the expense ratios of ETFs tend to be less than those of mutual funds.

Mutual Fund Returns

Do actively managed mutual funds outperform stock indices such as the S&P 500? Some funds in some years do very well, but this could be the result of good luck rather than good investment management. Two key questions for researchers are:

1. Do actively managed funds outperform stock indices on average?
2. Do funds that outperform the market in one year continue to do so?

The answer to both questions appears to be no. In a classic study, Jensen (1969) performed tests on mutual fund performance using 10 years of data on 115 funds.[5] He calculated the alpha for each fund in each year. Alpha is the return earned in excess of that predicted by the capital asset pricing model. The average alpha was about zero before all expenses and negative after expenses were considered. Jensen tested whether funds with positive alphas tended to continue to earn positive alphas. His results are summarized in Table 3-3. The first row shows that 574 positive alphas were observed from the 1,150 observations (close to 50%). Of these positive alphas, 50.4% were followed by another year of positive alpha. Row two shows that, when two years of positive alphas have been observed, there is a 52% chance that the next year will have a positive alpha, and so on. The results show that, when a manager has achieved above average returns for one year (or several years in a row), there is still only a probability of about 50% of achieving above average returns the next year. The results suggest that managers who obtain positive alphas do so because of luck rather than skill. It is possible that there are some managers who are able to perform consistently above average, but they are a very small percentage of the total. More recent studies have confirmed Jensen's conclusions. On average,

TABLE 3-3 Consistency of Good Performance by Mutual Funds

Number of Consecutive Years of Positive Alpha	Number of Observations	Percentage of Observations When Next Alpha Is Positive
1	574	50.4
2	312	52.0
3	161	53.4
4	79	55.8
5	41	46.4
6	17	35.3

[5] See M. C. Jensen, "Risk, the Pricing of Capital Assets and the Evaluation of Investment Portfolios," *Journal of Business* 42 (April 1969): 167–247.

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BOX 3-1 Mutual Fund Returns Can Be Misleading

Suppose that the following is a sequence of returns per annum reported by a mutual fund manager over the last five years (measured using annual compounding):

15%, 20%, 30%, −20%, 25%

The arithmetic mean of the returns, calculated by taking the sum of the returns and dividing by 5, is 14%. However, an investor would actually earn less than 14% per annum by leaving the money invested in the fund for five years. The dollar value of $100 at the end of the five years would be

$$100 \times 1.15 \times 1.20 \times 1.30 \times 0.80 \times 1.25 = \$179.40$$

By contrast, a 14% return (with annual compounding) would give

$$100 \times 1.14^5 = \$192.54$$

The return that gives $179.40 at the end of five years is 12.4%. This is because

$$100 \times (1.124)^5 = 179.40$$

What average return should the fund manager report? It is tempting for the manager to make a statement such as: "The average of the returns per year that we have realized in the last five years is 14%." Although true, this is misleading. It is much less misleading to say: "The average return realized by someone who invested with us for the last five years is 12.4% per year." In some jurisdictions, regulations require fund managers to report returns the second way.

This phenomenon is an example of a result that is well known by mathematicians. The geometric mean of a set of numbers (not all the same) is always less than the arithmetic mean. In our example, the return multipliers each year are 1.15, 1.20, 1.30, 0.80, and 1.25. The arithmetic mean of these numbers is 1.140, but the geometric mean is only 1.124. An investor who keeps an investment for several years earns a return corresponding to the geometric mean, not the arithmetic mean.

mutual fund managers do not beat the market and past performance is not a good guide to future performance. The success of index funds shows that this research has influenced the views of many investors.

Mutual funds frequently advertise impressive returns. However, the fund being featured might be one fund out of many offered by the same organization that happens to have produced returns well above the average for the market. Distinguishing between good luck and good performance is always tricky. Suppose an asset management company has 32 funds following different trading strategies and assume that the fund managers have no particular skills, so that the return of each fund has a 50% chance of being greater than the market each year. The probability of a particular fund beating the market every year for the next five years is $(½)^5$ or $1/32$. This means that by chance one out of the 32 funds will show a great performance over the five-year period!

One point should be made about the way returns over several years are expressed. One mutual fund might advertise "The average of the returns per year that we have achieved over the last five years is 15%." Another might say "If you had invested your money in our mutual fund for the last five years your money would have grown at 15% per year." These statements sound the same, but are actually different, as illustrated by Box 3-1. In many countries, regulators have strict rules to ensure that mutual fund returns are not reported in a misleading way.

Regulation and Mutual Fund Scandals

Because they solicit funds from small retail customers, many of whom are unsophisticated, mutual funds are heavily regulated. The SEC is the primary regulator of mutual funds in the United States. Mutual funds must file a registration document with the SEC. Full and accurate financial information must be provided to prospective fund purchasers in a prospectus. There are rules to prevent conflicts of interest, fraud, and excessive fees.

Despite the regulations, there have been a number of scandals involving mutual funds. One of these involves *late trading*. As mentioned earlier in this chapter, if a request to buy or sell mutual fund shares is placed by an investor with a broker by 4 P.M. on any given business day, it is the NAV of the fund at 4 P.M. that determines the price that is paid or received by the investor. In practice, for various reasons, an order to buy or sell is sometimes not passed from a broker to a mutual fund until later than 4 P.M. This allows brokers to collude with investors and submit new orders or change existing orders after 4 P.M. The NAV of the fund at 4 P.M. still applies to the investors—even though they may be using information on market movements (particularly

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movements in overseas markets) after 4 P.M. Late trading is not permitted under SEC regulations, and there were a number of prosecutions in the early 2000s that led to multimillion-dollar payments and employees being fired.

Another scandal is known as *market timing*. This is a practice where favored clients are allowed to buy and sell mutual fund shares frequently (e.g., every few days) and in large quantities without penalty. One reason why they might want to do this is because they are indulging in the illegal practice of late trading. Another reason is that they are analyzing the impact of stocks whose prices have not been updated recently on the fund's NAV. Suppose that the price of a stock has not been updated for several hours. (This could be because it does not trade frequently or because it trades on an exchange in a country in a different time zone.) If the U.S. market has gone up (down) in the last few hours, the calculated NAV is likely to understate (overstate) the value of the underlying portfolio and there is a short-term trading opportunity. Taking advantage of this is not necessarily illegal. However, it may be illegal for the mutual fund to offer special trading privileges to favored customers because the costs (such as those associated with providing the liquidity necessary to accommodate frequent redemptions) are borne by all customers.

Other scandals have involved *front running* and *directed brokerage*. Front running occurs when a mutual fund is planning a big trade that is expected to move the market. It informs favored customers or partners before executing the trade, allowing them to trade for their own account first. Directed brokerage involves an improper arrangement between a mutual fund and a brokerage house where the brokerage house recommends the mutual fund to clients in return for receiving orders from the mutual fund for stock and bond trades.

HEDGE FUNDS

Hedge funds are different from mutual funds in that they are subject to very little regulation. This is because they accept funds only from financially sophisticated individuals and organizations. Examples of the regulations that affect mutual funds are the requirements that:

- Shares be redeemable at any time
- NAV be calculated daily
- Investment policies be disclosed
- The use of leverage be limited

Hedge funds are largely free from these regulations. This gives them a great deal of freedom to develop sophisticated, unconventional, and proprietary investment strategies. Hedge funds are sometimes referred to as *alternative investments*.

The first hedge fund, A. W. Jones & Co., was created by Alfred Winslow Jones in the United States in 1949. It was structured as a general partnership to avoid SEC regulations. Jones combined long positions in stocks considered to be undervalued with short positions in stocks considered to be overvalued. He used leverage to magnify returns. A performance fee equal to 20% of profits was charged to investors. The fund performed well and the term "hedge fund" was coined in a newspaper article written about A. W. Jones & Co. by Carol Loomis in 1966. The article showed that the fund's performance after allowing for fees was better than the most successful mutual funds. Not surprisingly, the article led to a great deal of interest in hedge funds and their investment approach. Other hedge fund pioneers were George Soros, Walter J. Schloss, and Julian Robertson.[6]

"Hedge fund" implies that risks are being hedged. The trading strategy of Jones did involve hedging. He had little exposure to the overall direction of the market because his long position (in stocks considered to be undervalued) at any given time was about the same size as his short position (in stocks considered to be overvalued). However, for some hedge funds, the word "hedge" is inappropriate because they take aggressive bets on the future direction of the market with no particular hedging policy.

Hedge funds have grown in popularity over the years, and it is estimated that more than $2 trillion was invested with them in 2014. However, as we will see later, hedge funds have performed less well than the S&P 500 between 2009 and 2013. Many hedge funds are registered in tax-favorable jurisdictions. For example, over 30% of hedge funds are domiciled in the Cayman Islands. Funds of funds have been set up to allocate funds to different hedge funds. Hedge funds are difficult to ignore. They account

[6] The famous investor, Warren Buffett, can also be considered to be a hedge fund pioneer. In 1956, he started Buffett Partnership LP with seven limited partners and $100,100. Buffett charged his partners 25% of profits above a hurdle rate of 25%. He searched for unique situations, merger arbitrage, spin-offs, and distressed debt opportunities and earned an average of 29.5% per year. The partnership was disbanded in 1969 and Berkshire Hathaway (a holding company, not a hedge fund) was formed.

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for a large part of the daily turnover on the New York and London stock exchanges. They are major players in the convertible bond, credit default swap, distressed debt, and non-investment-grade bond markets. They are also active participants in the ETF market, often taking short positions.

Fees

One characteristic of hedge funds that distinguishes them from mutual funds is that fees are higher and dependent on performance. An annual management fee that is usually between 1% and 3% of assets under management is charged. This is designed to meet operating costs—but there may be an additional fee for such things as audits, account administration, and trader bonuses. Moreover, an incentive fee that is usually between 15% and 30% of realized net profits (i.e., profits after management fees) is charged if the net profits are positive. This fee structure is designed to attract the most talented and sophisticated investment managers. Thus, a typical hedge fund fee schedule might be expressed as "2 plus 20%" indicating that the fund charges 2% per year of assets under management and 20% of net profit. On top of high fees there is usually a lock up period of at least one year during which invested funds cannot be withdrawn. Some hedge funds with good track records have sometimes charged much more than the average. An example is Jim Simons's Renaissance Technologies Corp., which has charged as much as "5 plus 44%." (Jim Simons is a former math professor whose wealth is estimated to exceed $10 billion.)

The agreements offered by hedge funds may include clauses that make the incentive fees more palatable. For example:

- There is sometimes a *hurdle rate*. This is the minimum return necessary for the incentive fee to be applicable.
- There is sometimes a *high-water mark clause*. This states that any previous losses must be recouped by new profits before an incentive fee applies. Because different investors place money with the fund at different times, the high-water mark is not necessarily the same for all investors. There may be a *proportional adjustment clause* stating that, if funds are withdrawn by investors, the amount of previous losses that has to be recouped is adjusted proportionally. Suppose a fund worth $200 million loses $40 million and $80 million of funds are withdrawn. The high-water mark clause on its own would require $40 million of profits on the remaining $80 million to be achieved before the incentive fee applied. The proportional adjustment clause would reduce this to $20 million because the fund is only half as big as it was when the loss was incurred.
- There is sometimes a *clawback clause* that allows investors to apply part or all of previous incentive fees to current losses. A portion of the incentive fees paid by the investor each year is then retained in a *recovery account*. This account is used to compensate investors for a percentage of any future losses.

Some hedge fund managers have become very rich from the generous fee schedules. In 2013, hedge fund managers reported as earning over $1 billion were George Soros of Soros Fund Management LLC, David Tepper of Appaloosa Management, John Paulson of Paulson and Co., Carl Icahn of Icahn Capital Management, Jim Simons of Renaissance Technologies, and Steve Cohen of SAC Capital. (SAC Capital no longer manages outside money. Eight of its employees, though not Cohen, and the firm itself had either pleaded guilty or been convicted of insider trading by April 2014.)

If an investor has a portfolio of investments in hedge funds, the fees paid can be quite high. As a simple example, suppose that an investment is divided equally between two funds, A and B. Both funds charge 2 plus 20%. In the first year, Fund A earns 20% while Fund B earns −10%. The investor's average return on investment before fees is $0.5 \times 20\% + 0.5 \times (-10\%)$ or 5%. The fees paid to fund A are $2\% + 0.2 \times (20 - 2)\%$ or 5.6%. The fees paid to Fund B are 2%. The average fee paid on the investment in the hedge funds is therefore 3.8%. The investor is left with a 1.2% return. This is half what the investor would get if 2 plus 20% were applied to the overall 5% return.

When a fund of funds is involved, there is an extra layer of fees and the investor's return after fees is even worse. A typical fee charged by a fund of hedge funds used to be 1% of assets under management plus 10% of the net (after management and incentive fees) profits of the hedge funds they invest in. These fees have gone down as a result of poor hedge fund performance. Suppose a fund of hedge funds divides its money equally between 10 hedge funds. All charge 2 plus 20% and the fund of hedge funds charges 1 plus 10%. It sounds as though the investor pays 3 plus 30%—but it can be much more than this. Suppose that five of the hedge funds lose 40% before fees and the other five make 40% before fees. An incentive fee of 20% of 38% or 7.6% has to be paid to each of the profitable

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hedge funds. The total incentive fee is therefore 3.8% of the funds invested. In addition there is a 2% annual fee paid to the hedge funds and 1% annual fee paid to the fund of funds. The investor's net return is −6.8% of the amount invested. (This is 6.8% less than the return on the underlying assets before fees.)

Incentives of Hedge Fund Managers

The fee structure gives hedge fund managers an incentive to make a profit. But it also encourages them to take risks. The hedge fund manager has a call option on the assets of the fund. As is well known, the value of a call option increases as the volatility of the underlying assets increases. This means that the hedge fund manager can increase the value of the option by taking risks that increase the volatility of the fund's assets. The fund manager has a particular incentive to do this when nearing the end of the period over which the incentive fee is calculated and the return to date is low or negative.

Suppose that a hedge fund manager is presented with an opportunity where there is a 0.4 probability of a 60% profit and a 0.6 probability of a 60% loss with the fees earned by the hedge fund manager being 2 plus 20%. The expected return of the investment is

$$0.4 \times 60\% + 0.6 \times (-60\%)$$

or −12%.

Even though this is a terrible expected return, the hedge fund manager might be tempted to accept the investment. If the investment produces a 60% profit, the hedge fund's fee is $2 + 0.2 \times 58$ or 13.6%. If the investment produces a 60% loss, the hedge fund's fee is 2%. The expected fee to the hedge fund is therefore

$$0.4 \times 13.6 + 0.6 \times 2 = 6.64$$

or 6.64% of the funds under administration. The expected management fee is 2% and the expected incentive fee is 4.64%.

To the investors in the hedge fund, the expected return is

$$0.4 \times (60 - 0.2 \times 58 - 2) + 0.6 \times (-60 - 2) = -18.64$$

or −18.64%.

The example is summarized in Table 3-4. It shows that the fee structure of a hedge fund gives its managers an incentive to take high risks even when expected returns are negative. The incentives may be reduced by hurdle rates, high-water mark clauses, and clawback clauses. However, these clauses are not always as useful to investors as they sound. One reason is that investors have to continue to invest with the fund to take advantage of them. Another is that, as losses mount up for a hedge fund, the hedge fund managers have an incentive to wind up the hedge fund and start a new one.

TABLE 3-4 Return from High-Risk Investment Where Returns of +60% and −60% Have Probabilities of 0.4 and 0.6, Respectively, and the Hedge Fund Charges 2 plus 20%

Expected return to hedge fund	6.64%
Expected return to investors	−18.64%
Overall expected return	−12.00%

The incentives we are talking about here are real. Imagine how you would feel as an investor in the hedge fund, Amaranth. One of its traders, Brian Hunter, liked to make huge bets on the price of natural gas. Until 2006, his bets were largely right and as a result he was regarded as a star trader. His remuneration including bonuses is reputed to have been close to $100 million in 2005. During 2006, his bets proved wrong and Amaranth, which had about $9 billion of assets under administration, lost a massive $6.5 billion. (This was even more than the loss of hedge fund Long-Term Capital Management in 1998.) Brian Hunter did not have to return the bonuses he had previously earned. Instead, he left Amaranth and tried to start his own hedge fund.

It is interesting to note that, in theory, two individuals can create a money machine as follows. One starts a hedge fund with a certain high risk (and secret) investment strategy. The other starts a hedge fund with an investment strategy that is the opposite of that followed by the first hedge fund. For example, if the first hedge fund decides to buy $1 million of silver, the second hedge fund shorts this amount of silver. At the time they start the funds, the two individuals enter into an agreement to share the incentive fees. One hedge fund (we do not know which one) is likely to do well and earn good incentive fees. The other will do badly and earn no incentive fees. Provided that they can find investors for their funds, they have a money machine!

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Prime Brokers

Prime brokers are the banks that offer services to hedge funds. Typically a hedge fund, when it is first started, will choose a particular bank as its prime broker. This bank handles the hedge fund's trades (which may be with the prime broker or with other financial institutions), carries out calculations each day to determine the collateral the hedge fund has to provide, borrows securities for the hedge fund when it wants to take short positions, provides cash management and portfolio reporting services, and makes loans to the hedge fund. In some cases, the prime broker provides risk management and consulting services and introduces the hedge fund to potential investors. The prime broker has a good understanding of the hedge fund's portfolio and will typically carry out stress tests on the portfolio to decide how much leverage it is prepared to offer the fund.

Although hedge funds are not heavily regulated, they do have to answer to their prime brokers. The prime broker is the main source of borrowed funds for a hedge fund. The prime broker monitors the risks being taken by the hedge fund and determines how much the hedge fund is allowed to borrow. Typically a hedge fund has to post securities with the prime broker as collateral for its loans. When it loses money, more collateral has to be posted. If it cannot post more collateral, it has no choice but to close out its trades. One thing the hedge fund has to think about is the possibility that it will enter into a trade that is correct in the long term, but loses money in the short term. Consider a hedge fund that thinks credit spreads are too high. It might be tempted to take a highly leveraged position where BBB-rated bonds are bought and Treasury bonds are shorted. However, there is the danger that credit spreads will increase before they decrease. In this case, the hedge fund might run out of collateral and be forced to close out its position at a huge loss.

As a hedge fund gets larger, it is likely to use more than one prime broker. This means that no one bank sees all its trades and has a complete understanding of its portfolio. The opportunity of transacting business with more than one prime broker gives a hedge fund more negotiating clout to reduce the fees it pays. Goldman Sachs, Morgan Stanley, and many other large banks offer prime broker services to hedge funds and find them to be an important contributor to their profits.[7]

HEDGE FUND STRATEGIES

In this section we will discuss some of the strategies followed by hedge funds. Our classification is similar to the one used by Dow Jones Credit Suisse, which provides indices tracking hedge fund performance. Not all hedge funds can be classified in the way indicated. Some follow more than one of the strategies mentioned and some follow strategies that are not listed. (For example, there are funds specializing in weather derivatives.)

Long/Short Equity

As described earlier, long/short equity strategies were used by hedge fund pioneer Alfred Winslow Jones. They continue to be among the most popular of hedge fund strategies. The hedge fund manager identifies a set of stocks that are considered to be undervalued by the market and a set that are considered to be overvalued. The manager takes a long position in the first set and a short position in the second set. Typically, the hedge fund has to pay the prime broker a fee (perhaps 1% per year) to rent the shares that are borrowed for the short position.

Long/short equity strategies are all about stock picking. If the overvalued and undervalued stocks have been picked well, the strategies should give good returns in both bull and bear markets. Hedge fund managers often concentrate on smaller stocks that are not well covered by analysts and research the stocks extensively using fundamental analysis, as pioneered by Benjamin Graham. The hedge fund manager may choose to maintain a net long bias where the shorts are of smaller magnitude than the

[7] Although a bank is taking some risks when it lends to a hedge fund, it is also true that a hedge fund is taking some risks when it chooses a prime broker. Many hedge funds that chose Lehman Brothers as their prime broker found that they could not access assets, which they had placed with Lehman Brothers as collateral, when the company went bankrupt in 2008.

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longs or a net short bias where the reverse is true. Alfred Winslow Jones maintained a net long bias in his successful use of long/short equity strategies.

An *equity-market-neutral* fund is one where longs and shorts are matched in some way. A *dollar-neutral* fund is an equity-market-neutral fund where the dollar amount of the long position equals the dollar amount of the short position. A *beta-neutral fund* is a more sophisticated equity-market-neutral fund where the weighted average beta of the shares in the long portfolio equals the weighted average beta of the shares in the short portfolio so that the overall beta of the portfolio is zero. If the capital asset pricing model is true, the beta-neutral fund should be totally insensitive to market movements. Long and short positions in index futures are sometimes used to maintain a beta-neutral position.

Sometimes equity market neutral funds go one step further. They maintain *sector neutrality* where long and short positions are balanced by industry sectors or *factor neutrality* where the exposure to factors such as the price of oil, the level of interest rates, or the rate of inflation is neutralized.

Dedicated Short

Managers of dedicated short funds look exclusively for overvalued companies and sell them short. They are attempting to take advantage of the fact that brokers and analysts are reluctant to issue sell recommendations—even though one might reasonably expect the number of companies overvalued by the stock market to be approximately the same as the number of companies undervalued at any given time. Typically, the companies chosen are those with weak financials, those that change their auditors regularly, those that delay filing reports with the SEC, companies in industries with overcapacity, companies suing or attempting to silence their short sellers, and so on.

Distressed Securities

Bonds with credit ratings of BB or lower are known as "non-investment-grade" or "junk" bonds. Those with a credit rating of CCC are referred to as "distressed" and those with a credit rating of D are in default. Typically, distressed bonds sell at a big discount to their par value and provide a yield that is over 1,000 basis points (10%) more than the yield on Treasury bonds. Of course, an investor only earns this yield if the required interest and principal payments are actually made.

The managers of funds specializing in distressed securities carefully calculate a fair value for distressed securities by considering possible future scenarios and their probabilities. Distressed debt cannot usually be shorted and so they are searching for debt that is undervalued by the market. Bankruptcy proceedings usually lead to a reorganization or liquidation of a company. The fund managers understand the legal system, know priorities in the event of liquidation, estimate recovery rates, consider actions likely to be taken by management, and so on.

Some funds are passive investors. They buy distressed debt when the price is below its fair value and wait. Other hedge funds adopt an active approach. They might purchase a sufficiently large position in outstanding debt claims so that they have the right to influence a reorganization proposal. In Chapter 11 reorganizations in the United States, each class of claims must approve a reorganization proposal with a two-thirds majority. This means that one-third of an outstanding issue can be sufficient to stop a reorganization proposed by management or other stakeholders. In a reorganization of a company, the equity is often worthless and the outstanding debt is converted into new equity. Sometimes, the goal of an active manager is to buy more than one-third of the debt, obtain control of a target company, and then find a way to extract wealth from it.

Merger Arbitrage

Merger arbitrage involves trading after a merger or acquisition is announced in the hope that the announced deal will take place. There are two main types of deals: cash deals and share-for-share exchanges.

Consider first cash deals. Suppose that Company A announces that it is prepared to acquire all the shares of Company B for $30 per share. Suppose the shares of Company B were trading at $20 prior to the announcement. Immediately after the announcement its share price might jump to $28. It does not jump immediately to $30 because (a) there is some chance that the deal will not go through and (b) it may take some time for the full impact of the deal to be reflected in market prices. Merger-arbitrage hedge funds buy the shares in Company B for $28 and wait. If the acquisition goes through at $30, the

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fund makes a profit of $2 per share. If it goes through at a higher price, the profit is higher. However, if for any reason the deal does not go through, the hedge fund will take a loss.

Consider next a share-for-share exchange. Suppose that Company A announces that it is willing to exchange one of its shares for four of Company B's shares. Assume that Company B's shares were trading at 15% of the price of Company A's shares prior to the announcement. After the announcement, Company B's share price might rise to 22% of Company A's share price. A merger-arbitrage hedge fund would buy a certain amount of Company B's stock and at the same time short a quarter as much of Company A's stock. This strategy generates a profit if the deal goes ahead at the announced share-for-share exchange ratio or one that is more favorable to Company B.

Merger-arbitrage hedge funds can generate steady, but not stellar, returns. It is important to distinguish merger arbitrage from the activities of Ivan Boesky and others who used inside information to trade before mergers became public knowledge.[8] Trading on inside information is illegal. Ivan Boesky was sentenced to three years in prison and fined $100 million.

Convertible Arbitrage

Convertible bonds are bonds that can be converted into the equity of the bond issuer at certain specified future times with the number of shares received in exchange for a bond possibly depending on the time of the conversion. The issuer usually has the right to call the bond (i.e., buy it back for a prespecified price) in certain circumstances. Usually, the issuer announces its intention to call the bond as a way of forcing the holder to convert the bond into equity immediately. (If the bond is not called, the holder is likely to postpone the decision to convert it into equity for as long as possible.)

A convertible arbitrage hedge fund has typically developed a sophisticated model for valuing convertible bonds. The convertible bond price depends in a complex way on the price of the underlying equity, its volatility, the level of interest rates, and the chance of the issuer defaulting.

[8] The Michael Douglas character of Gordon Gekko in the award-winning movie *Wall Street* was based on Ivan Boesky.

Many convertible bonds trade at prices below their fair value. Hedge fund managers buy the bond and then hedge their risks by shorting the stock. This is an application of delta hedging. Interest rate risk and credit risk can be hedged by shorting nonconvertible bonds that are issued by the company that issued the convertible bond. Alternatively, the managers can take positions in interest rate futures contracts, asset swaps, and credit default swaps to accomplish this hedging.

Fixed Income Arbitrage

The basic tool of fixed income trading is the zero-coupon yield curve. One strategy followed by hedge fund managers that engage in fixed income arbitrage is a *relative value* strategy, where they buy bonds that the zero-coupon yield curve indicates are undervalued by the market and sell bonds that it indicates are overvalued. *Market-neutral* strategies are similar to relative value strategies except that the hedge fund manager tries to ensure that the fund has no exposure to interest rate movements.

Some fixed-income hedge fund managers follow directional strategies where they take a position based on a belief that a certain spread between interest rates, or interest rates themselves, will move in a certain direction. Usually they have a lot of leverage and have to post collateral. They are therefore taking the risk that they are right in the long term, but that the market moves against them in the short term so that they cannot post collateral and are forced to close out their positions at a loss. This is what happened to Long-Term Capital Management.

Emerging Markets

Emerging market hedge funds specialize in investments associated with developing countries. Some of these funds focus on equity investments. They screen emerging market companies looking for shares that are overvalued or undervalued. They gather information by traveling, attending conferences, meeting with analysts, talking to management, and employing consultants. Usually they invest in securities trading on the local exchange, but sometimes they use American Depository Receipts (ADRs). ADRs are certificates issued in the United States and traded on a U.S. exchange. They are backed by shares of a foreign company. ADRs may have better liquidity and lower transactions costs than the underlying foreign

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shares. Sometimes there are price discrepancies between ADRs and the underlying shares giving rise to arbitrage opportunities.

Another type of investment is debt issued by an emerging market country. Eurobonds are bonds issued by the country and denominated in a hard currency such as the U.S. dollar or the euro. Local currency bonds are bonds denominated in the local currency. Hedge funds invest in both types of bonds. They can be risky: countries such as Russia, Argentina, Brazil, and Venezuela have defaulted several times on their debt.

Global Macro

Global macro is the hedge fund strategy used by star managers such as George Soros and Julian Robertson. Global macro hedge fund managers carry out trades that reflect global macroeconomic trends. They look for situations where markets have, for whatever reason, moved away from equilibrium and place large bets that they will move back into equilibrium. Often the bets are on exchange rates and interest rates. A global macro strategy was used in 1992 when George Soros's Quantum Fund gained $1 billion by betting that the British pound would decrease in value. More recently, hedge funds have (with mixed results) placed bets that the huge U.S. balance of payments deficit would cause the value of the U.S. dollar to decline. The main problem for global macro funds is that they do not know when equilibrium will be restored. World markets can for various reasons be in disequilibrium for long periods of time.

Managed Futures

Hedge fund managers that use managed futures strategies attempt to predict future movements in commodity prices. Some rely on the manager's judgment; others use computer programs to generate trades. Some managers base their trading on technical analysis, which analyzes past price patterns to predict the future. Others use fundamental analysis, which involves calculating a fair value for the commodity from economic, political, and other relevant factors.

When technical analysis is used, trading rules are usually first tested on historical data. This is known as back-testing. If (as is often the case) a trading rule has come from an analysis of past data, trading rules should be tested out of sample (that is, on data that are different from the data used to generate the rules). Analysts should be aware of the perils of data mining. Suppose thousands of different trading rules are generated and then tested on historical data. Just by chance a few of the trading rules will perform very well—but this does not mean that they will perform well in the future.

HEDGE FUND PERFORMANCE

It is not as easy to assess hedge fund performance as it is to assess mutual fund performance. There is no data set that records the returns of all hedge funds. For the Tass hedge funds database, which is available to researchers, participation by hedge funds is voluntary. Small hedge funds and those with poor track records often do not report their returns and are therefore not included in the data set. When returns are reported by a hedge fund, the database is usually backfilled with the fund's previous returns. This creates a bias in the returns that are in the data set because, as just mentioned, the hedge funds that decide to start providing data are likely to be the ones doing well. When this bias is removed, some researchers have argued, hedge fund returns have historically been no better than mutual fund returns, particularly when fees are taken into account.

Arguably, hedge funds can improve the risk-return tradeoffs available to pension plans. This is because pension plans cannot (or choose not to) take short positions, obtain leverage, invest in derivatives, and engage in many of the complex trades that are favored by hedge funds. Investing in a hedge fund is a simple way in which a pension fund can (for a fee) expand the scope of its investing. This may improve its efficient frontier.

It is not uncommon for hedge funds to report good returns for a few years and then "blow up." Long-Term Capital Management reported returns (before fees) of 28%, 59%, 57%, and 17% in 1994, 1995, 1996, and 1997, respectively. In 1998, it lost virtually all its capital. Some people have argued that hedge fund returns are like the returns from writing out-of-the-money options. Most of the time, the options cost nothing, but every so often they are very expensive.

This may be unfair. Advocates of hedge funds would argue that hedge fund managers search for profitable opportunities that other investors do not have the

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TABLE 3-5 Performance of Hedge Funds

Year	Return on Hedge Fund Index (%)	S&P 500 Return Including Dividends (%)
2008	-15.66	-37.00
2009	18.57	26.46
2010	10.95	15.06
2011	-2.52	2.11
2012	7.67	16.00
2013	9.73	32.39

resources or expertise to find. They would point out that the top hedge fund managers have been very successful at finding these opportunities.

Prior to 2008, hedge funds performed quite well. In 2008, hedge funds on average lost money but provided a better performance than the S&P 500. During the years 2009 to 2013, the S&P 500 provided a much better return than the average hedge fund.[9] The Credit Suisse hedge fund index is an asset-weighted index of hedge fund returns after fees (potentially having some of the biases mentioned earlier). Table 4-5 compares returns given by the index with total returns from the S&P 500.

SUMMARY

Mutual funds offer a way small investors can capture the benefits of diversification. Overall, the evidence is that actively managed funds do not outperform the market and this has led many investors to choose funds that are designed to track a market index such as the S&P 500. Mutual funds are highly regulated. They cannot take short positions or use very much leverage and must allow investors to redeem their shares in the mutual fund at any time. Most mutual funds are open-end funds, so that the number of shares in the fund increases (decreases) as investors contribute (withdraw) funds. An open-end mutual fund calculates the net asset value of shares in the fund at 4 P.M. each business day and this is the price used for all buy and sell orders placed in the previous 24 hours. A closed-end fund has a fixed number of shares that trade in the same way as the shares of any other corporation.

Exchange-traded funds (ETFs) are proving to be popular alternatives to open- and closed-end funds. The shares held by the fund are known at any given time. Large institutional investors can exchange shares in the fund at any time for the assets underlying the shares, and vice versa. This ensures that the shares in the ETF (unlike shares in a closed-end fund) trade at a price very close to the fund's net asset value. Shares in an ETF can be traded at any time (not just at 4 P.M.) and shares in an ETF (unlike shares in an open-end mutual fund) can be shorted.

Hedge funds cater to the needs of large investors. Compared to mutual funds, they are subject to very few regulations and restrictions. Hedge funds charge investors much higher fees than mutual funds. The fee for a typical fund is "2 plus 20%." This means that the fund charges a management fee of 2% per year and receives 20% of the profit after management fees have been paid generated by the fund if this is positive. Hedge fund managers have a call option on the assets of the fund and, as a result, may have an incentive to take high risks.

Among the strategies followed by hedge funds are long/short equity, dedicated short, distressed securities, merger arbitrage, convertible arbitrage, fixed income arbitrage, emerging markets, global macro, and managed futures. The jury is still out on whether hedge funds provide better risk-return trade-offs than index funds after fees. There is an unfortunate tendency for hedge funds to provide excellent returns for a number of years and then report a disastrous loss.

[9] It should be pointed out that hedge funds often have a beta less than one (for example, long-short equity funds are often designed to have a beta close to zero), so a return less than the S&P 500 during periods when the market does very well does not necessarily indicate a negative alpha.

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Introduction

4

Learning Objectives

After completing this reading you should be able to:

- Describe the over-the-counter market, distinguish it from trading on an exchange, and evaluate its advantages and disadvantages.
- Differentiate between options, forwards, and futures contracts.
- Identify and calculate option and forward contract payoffs.
- Calculate and compare the payoffs from hedging strategies involving forward contracts and options.
- Calculate and compare the payoffs from speculative strategies involving futures and options.
- Calculate an arbitrage payoff and describe how arbitrage opportunities are temporary.
- Describe some of the risks that can arise from the use of derivatives.

Excerpt is Chapter 1 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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In the last 40 years, derivatives have become increasingly important in finance. Futures and options are actively traded on many exchanges throughout the world. Many different types of forward contracts, swaps, options, and other derivatives are entered into by financial institutions, fund managers, and corporate treasurers in the over-the-counter market. Derivatives are added to bond issues, used in executive compensation plans, embedded in capital investment opportunities, used to transfer risks in mortgages from the original lenders to investors, and so on. We have now reached the stage where those who work in finance, and many who work outside finance, need to understand how derivatives work, how they are used, and how they are priced.

Whether you love derivatives or hate them, you cannot ignore them! The derivatives market is huge—much bigger than the stock market when measured in terms of underlying assets. The value of the assets underlying outstanding derivatives transactions is several times the world gross domestic product. As we shall see in this chapter, derivatives can be used for hedging or speculation or arbitrage. They play a key role in transferring a wide range of risks in the economy from one entity to another.

A *derivative* can be defined as a financial instrument whose value depends on (or derives from) the values of other, more basic, underlying variables. Very often the variables underlying derivatives are the prices of traded assets. A stock option, for example, is a derivative whose value is dependent on the price of a stock. However, derivatives can be dependent on almost any variable, from the price of hogs to the amount of snow falling at a certain ski resort.

Since the first edition of this book was published in 1988 there have been many developments in derivatives markets. There is now active trading in credit derivatives, electricity derivatives, weather derivatives, and insurance derivatives. Many new types of interest rate, foreign exchange, and equity derivative products have been created. There have been many new ideas in risk management and risk measurement. Capital investment appraisal now often involves the evaluation of what are known as *real options*. Many new regulations have been introduced covering over-the-counter derivatives markets. The book has kept up with all these developments.

Derivatives markets have come under a great deal of criticism because of their role in the credit crisis that started in 2007. Derivative products were created from portfolios of risky mortgages in the United States using a procedure known as securitization. Many of the products that were created became worthless when house prices declined. Financial institutions, and investors throughout the world, lost a huge amount of money and the world was plunged into the worst recession it had experienced in 75 years. As a result of the credit crisis, derivatives markets are now more heavily regulated than they used to be. For example, banks are required to keep more capital for the risks they are taking and to pay more attention to liquidity.

The way banks value derivatives has evolved through time. Collateral arrangements and credit issues are now given much more attention than in the past. Although it cannot be justified theoretically, many banks have changed the proxies they use for the "risk-free" interest rate to reflect their funding costs.

In this chapter, we take a first look at derivatives markets and how they are changing. We describe forward, futures, and options markets and provide an overview of how they are used by hedgers, speculators, and arbitrageurs. Later chapters will give more details and elaborate on many of the points made here.

EXCHANGE-TRADED MARKETS

A derivatives exchange is a market where individuals trade standardized contracts that have been defined by the exchange. Derivatives exchanges have existed for a long time. The Chicago Board of Trade (CBOT) was established in 1848 to bring farmers and merchants together. Initially its main task was to standardize the quantities and qualities of the grains that were traded. Within a few years, the first futures-type contract was developed. It was known as a *to-arrive contract*. Speculators soon became interested in the contract and found trading the contract to be an attractive alternative to trading the grain itself. A rival futures exchange, the Chicago Mercantile Exchange (CME), was established in 1919. Now futures exchanges exist all over the world. (See the appendix at the end of the book.) The CME and CBOT have merged to form the CME Group (www.cmegroup.com), which also includes the New York Mercantile Exchange, the commodity exchange (COMEX), and the Kansas City Board of Trade (KCBT).

The Chicago Board Options Exchange (CBOE, www.cboe.com) started trading call option contracts on 16 stocks

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in 1973. Options had traded prior to 1973, but the CBOE succeeded in creating an orderly market with well-defined contracts. Put option contracts started trading on the exchange in 1977. The CBOE now trades options on over 2,500 stocks and many different stock indices. Like futures, options have proved to be very popular contracts. Many other exchanges throughout the world now trade options. The underlying assets include foreign currencies and futures contracts as well as stocks and stock indices.

Once two traders have agreed on a trade, it is handled by the exchange clearing house. This stands between the two traders and manages the risks. Suppose, for example, that trader A agrees to buy 100 ounces of gold from trader B at a future time for $1,450 per ounce. The result of this trade will be that A has a contract to buy 100 ounces of gold from the clearing house at $1,450 per ounce and B has a contract to sell 100 ounces of gold to the clearing house for $1,450 per ounce. The advantage of this arrangement is that traders do not have to worry about the creditworthiness of the people they are trading with. The clearing house takes care of credit risk by requiring each of the two traders to deposit funds (known as margin) with the clearing house to ensure that they will live up to their obligations. Margin requirements and the operation of clearing houses are discussed in more detail in Chapter 5.

Electronic Markets

Traditionally derivatives exchanges have used what is known as the *open outcry system*. This involves traders physically meeting on the floor of the exchange, shouting, and using a complicated set of hand signals to indicate the trades they would like to carry out. Exchanges have largely replaced the open outcry system by *electronic trading*. This involves traders entering their desired trades at a keyboard and a computer being used to match buyers and sellers. The open outcry system has its advocates, but, as time passes, it is becoming less and less used.

Electronic trading has led to a growth in high-frequency and algorithmic trading. This involves the use of computer programs to initiate trades, often without human intervention, and has become an important feature of derivatives markets.

OVER-THE-COUNTER MARKETS

Not all derivatives trading is on exchanges. Many trades take place in the *over-the-counter* (OTC) market. Banks, other large financial institutions, fund managers, and corporations are the main participants in OTC derivatives markets. Once an OTC trade has been agreed, the two parties can either present it to a central counterparty (CCP) or clear the trade bilaterally. A CCP is like an exchange clearing house. It stands between the two parties to the derivatives transaction so that one party does not have to bear the risk that the other party will default. When trades are cleared bilaterally, the two parties have usually signed an agreement covering all their transactions with each other. The issues covered in the agreement include the circumstances under which outstanding transactions can be terminated, how settlement amounts are calculated in the event of a termination, and how the collateral (if any) that must be posted by each side is calculated. CCPs and bilateral clearing are discussed in more detail in Chapter 5.

Traditionally, participants in the OTC derivatives markets have contacted each other directly by phone and email, or have found counterparties for their trades using an inter-dealer broker. Banks often act as market makers for the more commonly traded instruments. This means that they are always prepared to quote a bid price (at which they are prepared to take one side of a derivatives transaction) and an offer price (at which they are prepared to take the other side).

Prior to the credit crisis, which started in 2007, OTC derivatives markets were largely unregulated. Following the credit crisis and the failure of Lehman Brothers (see Box 4-1), we have seen the development of many new regulations affecting the operation of OTC markets. The purpose of the regulations is to improve the transparency of OTC markets, improve market efficiency, and reduce systemic risk (see Box 4-2). The over-the-counter market in some respects is being forced to become more like the exchange-traded market. Three important changes are:

1. Standardized OTC derivatives in the United States must, whenever possible, be traded on what are referred to as *swap execution facilities* (SEFs). These are platforms where market participants can post bid and offer quotes and where market participants can choose to trade by accepting the quotes of other market participants.

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BOX 4-1 The Lehman Bankruptcy

On September 15, 2008, Lehman Brothers filed for bankruptcy. This was the largest bankruptcy in US history and its ramifications were felt throughout derivatives markets. Almost until the end, it seemed as though there was a good chance that Lehman would survive. A number of companies (e.g., the Korean Development Bank, Barclays Bank in the UK, and Bank of America) expressed interest in buying it, but none of these was able to close a deal. Many people thought that Lehman was "too big to fail" and that the US government would have to bail it out if no purchaser could be found. This proved not to be the case.

How did this happen? It was a combination of high leverage, risky investments, and liquidity problems. Commercial banks that take deposits are subject to regulations on the amount of capital they must keep. Lehman was an investment bank and not subject to these regulations. By 2007, its leverage ratio had increased to 31:1, which means that a 3–4% decline in the value of its assets would wipe out its capital. Dick Fuld, Lehman's Chairman and Chief Executive Officer, encouraged an aggressive deal-making, risk-taking culture. He is reported to have told his executives: "Every day is a battle. You have to kill the enemy." The Chief Risk Officer at Lehman was competent, but did not have much influence and was even removed from the executive committee in 2007. The risks taken by Lehman included large positions in the instruments created from subprime mortgages. Lehman funded much of its operations with short-term debt. When there was a loss of confidence in the company, lenders refused to roll over this funding, forcing it into bankruptcy.

Lehman was very active in the over-the-counter derivatives markets. It had over a million transactions outstanding with about 8,000 different counterparties. Lehman's counterparties were often required to post collateral and this collateral had in many cases been used by Lehman for various purposes. It is easy to see that sorting out who owes what to whom in this type of situation is a nightmare!

2. There is a requirement in most parts of the world that a CCP be used for most standardized derivatives transactions.
3. All trades must be reported to a central registry.

Market Size

Both the over-the-counter and the exchange-traded market for derivatives are huge. The number of derivatives transactions per year in OTC markets is smaller than in exchange-traded markets, but the average size of the transactions is much greater. Although the statistics that are collected for the two markets are not exactly comparable, it is clear that the over-the-counter market is much larger than the exchange-traded market. The Bank for International Settlements (www.bis.org) started collecting statistics on the markets in 1998. Figure 4-1 compares (a) the estimated total principal amounts underlying transactions that were outstanding in the over-the-counter markets between June 1998 and December 2012 and (b) the estimated total value of the assets underlying exchange-traded contracts during the same period. Using these measures, by December 2012 the over-the-counter market had grown to $632.6 trillion and the exchange-traded market had grown to $52.6 trillion.[1]

In interpreting these numbers, we should bear in mind that the principal underlying an over-the-counter transaction is not the same as its value. An example of an over-the-counter transaction is an agreement to buy 100 million US dollars with British pounds at a predetermined exchange rate in 1 year. The total principal amount underlying this transaction is $100 million. However, the value of the transaction might be only $1 million. The Bank

BOX 4-2 Systemic Risk

Systemic risk is the risk that a default by one financial institution will create a "ripple effect" that leads to defaults by other financial institutions and threatens the stability of the financial system. There are huge numbers of over-the-counter transactions between banks. If Bank A fails, Bank B may take a huge loss on the transactions it has with Bank A. This in turn could lead to Bank B failing. Bank C that has many outstanding transactions with both Bank A and Bank B might then take a large loss and experience severe financial difficulties; and so on.

The financial system has survived defaults such as Drexel in 1990 and Lehman Brothers in 2008, but regulators continue to be concerned. During the market turmoil of 2007 and 2008, many large financial institutions were bailed out, rather than being allowed to fail, because governments were concerned about systemic risk.

[1] When a CCP stands between two sides in an OTC transaction, two transactions are considered to have been created for the purposes of the BIS statistics.

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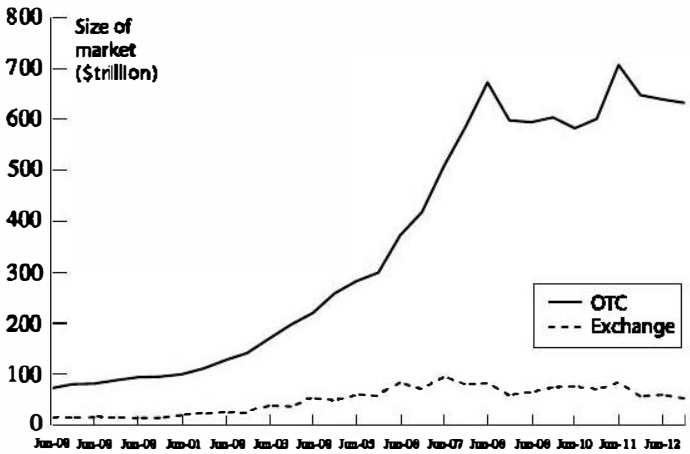

FIGURE 4-1 Size of over-the-counter and exchange-traded derivatives markets.

for International Settlements estimates the gross market value of all over-the-counter transactions outstanding in December 2012 to be about $24.7 trillion.[2]

FORWARD CONTRACTS

A relatively simple derivative is a *forward contract*. It is an agreement to buy or sell an asset at a certain future time for a certain price. It can be contrasted with a *spot contract*, which is an agreement to buy or sell an asset almost immediately. A forward contract is traded in the over-the-counter market—usually between two financial institutions or between a financial institution and one of its clients.

One of the parties to a forward contract assumes a *long position* and agrees to buy the underlying asset on a certain specified future date for a certain specified price. The other party assumes a *short position* and agrees to sell the asset on the same date for the same price.

Forward contracts on foreign exchange are very popular. Most large banks employ both spot and forward foreign-exchange traders. As we shall see in a later chapter, there is a relationship between forward prices, spot prices, and interest rates in the two currencies. Table 4-1 provides quotes for the exchange rate between the British pound (GBP) and the US dollar (USD) that might be made by a

TABLE 4-1 Spot and Forward Quotes for the USD/GBP Exchange Rate, May 6, 2013 (GBP = British Pound; USD = US Dollar; Quote Is Number of USD per GBP)

	Bid	Offer
Spot	1.5541	1.5545
1-month forward	1.5538	1.5543
3-month forward	1.5533	1.5538
6-month forward	1.5526	1.5532

large international bank on May 6, 2013. The quote is for the number of USD per GBP. The first row indicates that the bank is prepared to buy GBP (also known as sterling) in the spot market (i.e., for virtually immediate delivery) at the rate of $1.5541 per GBP and sell sterling in the spot market at $1.5545 per GBP. The second, third, and fourth rows indicate that the bank is prepared to buy sterling in 1, 3, and 6 months at $1.5538, $1.5533, and $1.5526 per GBP, respectively, and to sell sterling in 1, 3, and 6 months at $1.5543, $1.5538, and $1.5532 per GBP, respectively.

Forward contracts can be used to hedge foreign currency risk. Suppose that, on May 6, 2013, the treasurer of a US corporation knows that the corporation will pay £1 million in 6 months (i.e., on November 6, 2013) and wants to hedge against exchange rate moves. Using the quotes in Table 4-1, the treasurer can agree to buy £1 million 6 months forward at an exchange rate of 1.5532. The corporation then has a long forward contract on GBP. It has agreed that on November 6, 2013, it will buy £1 million from the bank for $1.5532 million. The bank has a short forward contract on GBP. It has agreed that on November 6, 2013, it will sell £1 million for $1.5532 million. Both sides have made a binding commitment.

Payoffs from Forward Contracts

Consider the position of the corporation in the trade we have just described. What are the possible outcomes? The forward contract obligates the corporation to buy £1 million for $1,553,200. If the spot exchange rate rose to, say, 1.6000, at the end of the 6 months, the forward contract would be worth $46,800 (= $1,600,000 − $1,553,200) to the corporation. It would enable £1 million to be purchased at an exchange rate of 1.5532 rather than 1.6000. Similarly, if the spot exchange rate fell to 1.5000 at the

[2] A contract that is worth $1 million to one side and −$1 million to the other side would be counted as having a gross market value of $1 million.

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end of the 6 months, the forward contract would have a negative value to the corporation of $53,200 because it would lead to the corporation paying $53,200 more than the market price for the sterling.

In general, the payoff from a long position in a forward contract on one unit of an asset is

$$S_T - K$$

where K is the delivery price and S_T is the spot price of the asset at maturity of the contract. This is because the holder of the contract is obligated to buy an asset worth S_T for K. Similarly, the payoff from a short position in a forward contract on one unit of an asset is

$$K - S_T$$

These payoffs can be positive or negative. They are illustrated in Figure 4-2. Because it costs nothing to enter into a forward contract, the payoff from the contract is also the trader's total gain or loss from the contract.

In the example just considered, K = 1:5532 and the corporation has a long contract. When S_T = 1:6000, the payoff is $0.0468 per £1; when S_T = 1:5000, it is −$0.0532 per £1.

Forward Prices and Spot Prices

We shall be discussing in some detail the relationship between spot and forward prices in Chapter 8. For a quick preview of why the two are related, consider a stock that pays no dividend and is worth $60. You can borrow or lend money for 1 year at 5%. What should the 1-year forward price of the stock be?

The answer is $60 grossed up at 5% for 1 year, or $63. If the forward price is more than this, say $67, you could borrow $60, buy one share of the stock, and sell it forward for $67. After paying off the loan, you would net a profit of $4 in 1 year. If the forward price is less than $63, say $58, an investor owning the stock as part of a portfolio would sell the stock for $60 and enter into a forward contract to buy it back for $58 in 1 year. The proceeds of investment would be invested at 5% to earn $3. The investor would end up $5 better off than if the stock were kept in the portfolio for the year.

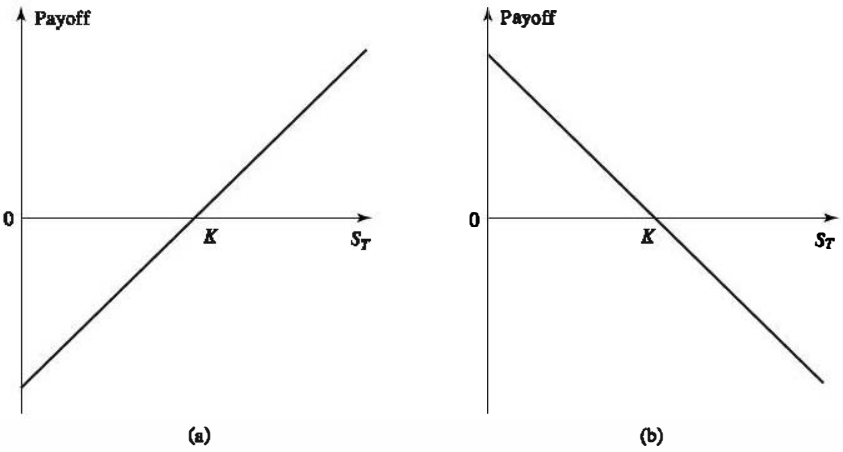

FIGURE 4-2 Payoffs from forward contracts: (a) long position, (b) short position. Delivery price = K; price of asset at contract maturity = S_T.

FUTURES CONTRACTS

Like a forward contract, a futures contract is an agreement between two parties to buy or sell an asset at a certain time in the future for a certain price. Unlike forward contracts, futures contracts are normally traded on an exchange. To make trading possible, the exchange specifies certain standardized features of the contract. As the two parties to the contract do not necessarily know each other, the exchange also provides a mechanism that gives the two parties a guarantee that the contract will be honored.

The largest exchanges on which futures contracts are traded are the Chicago Board of Trade (CBOT) and the Chicago Mercantile Exchange (CME), which have now merged to form the CME Group. On these and other exchanges throughout the world, a very wide range of commodities and financial assets form the underlying assets in the various contracts. The commodities include pork bellies, live cattle, sugar, wool, lumber, copper, aluminum, gold, and tin. The financial assets include stock indices, currencies, and Treasury bonds. Futures prices are regularly reported in the financial press. Suppose that, on September 1, the December futures price of gold is quoted as $1,380. This is the price, exclusive of commissions, at which traders can agree to buy or sell gold for December delivery. It is determined in the same way as other prices (i.e., by the laws of supply and demand). If more traders want to

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go long than to go short, the price goes up; if the reverse is true, then the price goes down.

Further details on issues such as margin requirements, daily settlement procedures, delivery procedures, bid–offer spreads, and the role of the exchange clearing house are given in Chapter 5.

OPTIONS

Options are traded both on exchanges and in the over-the-counter market. There are two types of option. A *call option* gives the holder the right to buy the underlying asset by a certain date for a certain price. A *put option* gives the holder the right to sell the underlying asset by a certain date for a certain price. The price in the contract is known as the *exercise price* or *strike price*; the date in the contract is known as the *expiration date* or *maturity*. *American options* can be exercised at any time up to the expiration date. *European options* can be exercised only on the expiration date itself.[3] Most of the options that are traded on exchanges are American. In the exchange-traded equity option market, one contract is usually an agreement to buy or sell 100 shares. European options are generally easier to analyze than American options, and some of the properties of an American option are frequently deduced from those of its European counterpart.

[3] Note that the terms *American* and *European* do not refer to the location of the option or the exchange. Some options trading on North American exchanges are European.

It should be emphasized that an option gives the holder the right to do something. The holder does not have to exercise this right. This is what distinguishes options from forwards and futures, where the holder is obligated to buy or sell the underlying asset. Whereas it costs nothing to enter into a forward or futures contract, there is a cost to acquiring an option.

The largest exchange in the world for trading stock options is the Chicago Board Options Exchange (CBOE; www.cboe.com). Table 4-2 gives the bid and offer quotes for some of the call options trading on Google (ticker symbol: GOOG) on May 8, 2013. Table 4-3 does the same for put options trading on Google on that date. The quotes are taken from the CBOE website. The Google stock price at the time of the quotes was bid 871.23, offer 871.37. The bid–offer spread on an option (as a percent of the price) is usually greater than that on the underlying stock and depends on the volume of trading. The option strike prices in Tables 4-2 and 4-3 are $820, $840, $860, $880, $900, and $920. The maturities are June 2013, September 2013, and December 2013. The June options expire on June 22, 2013, the September options on September 21, 2013, and the December options on December 21, 2013.

The tables illustrate a number of properties of options. The price of a call option decreases as the strike price increases, while the price of a put option increases as the strike price increases. Both types of option tend to become more valuable as their time to maturity increases. These properties of options will be discussed further in Chapter 12.

TABLE 4-2 Prices of Call Options on Google, May 8, 2013, from Quotes Provided by CBOE; Stock Price: Bid $871.23, Offer $871.37

Strike Price	June 2013		September 2013		December 2013	
($)	Bid	Offer	Bid	Offer	Bid	Offer
820	56.00	57.50	76.00	77.80	88.00	90.30
840	39.50	40.70	62.90	63.90	75.70	78.00
860	25.70	26.50	51.20	52.30	65.10	66.40
880	15.00	15.60	41.00	41.60	55.00	56.30
900	7.90	8.40	32.10	32.80	45.90	47.20
920	n.a.	n.a.	24.80	25.60	37.90	39.40

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TABLE 4-3 Prices of Put Options on Google, May 8, 2013, from Quotes Provided by CBOE; Stock Price: Bid $871.23, Offer $871.37

Strike Price	June 2013		September 2013		December 2013	
($)	Bid	Offer	Bid	Offer	Bid	Offer
820	5.00	5.50	24.20	24.90	36.20	37.50
840	8.40	8.90	31.00	31.80	43.90	45.10
860	14.30	14.80	39.20	40.10	52.60	53.90
880	23.40	24.40	48.80	49.80	62.40	63.70
900	36.20	37.30	59.20	60.90	73.40	75.00
920	n.a.	n.a.	71.60	73.50	85.50	87.40

Suppose an investor instructs a broker to buy one December call option contract on Google with a strike price of $880. The broker will relay these instructions to a trader at the CBOE and the deal will be done. The (offer) price indicated in Table 4-2 is $56.30. This is the price for an option to buy one share. In the United States, an option contract is a contract to buy or sell 100 shares. Therefore, the investor must arrange for $5,630 to be remitted to the exchange through the broker. The exchange will then arrange for this amount to be passed on to the party on the other side of the transaction.

In our example, the investor has obtained at a cost of $5,630 the right to buy 100 Google shares for $880 each. If the price of Google does not rise above $880 by December 21, 2013, the option is not exercised and the investor loses $5,630.[4] But if Google does well and the option is exercised when the bid price for the stock is $1,000, the investor is able to buy 100 shares at $880 and immediately sell them for $1,000 for a profit of $12,000, or $6,370 when the initial cost of the options is taken into account.[5]

An alternative trade would be to sell one September put option contract with a strike price of $840 at the bid price of $31.00. This would lead to an immediate cash inflow of 100 × 31.00 = $3,100. If the Google stock price stays above $840, the option is not exercised and the investor makes a profit of this amount. However, if stock price falls and the option is exercised when the stock price is $800, then there is a loss. The investor must buy 100 shares at $840 when they are worth only $800. This leads to a loss of $4,000, or $900 when the initial amount received for the option contract is taken into account.

The stock options trading on the CBOE are American. If we assume for simplicity that they are European, so that they can be exercised only at maturity, the investor's profit as a function of the final stock price for the two trades we have considered is shown in Figure 4-3.

Further details about the operation of options markets and how prices such as those in Tables 4-2 and 4-3 are determined by traders are given in later chapters. At this stage we note that there are four types of participants in options markets:

1. Buyers of calls
2. Sellers of calls
3. Buyers of puts
4. Sellers of puts.

Buyers are referred to as having *long positions*; sellers are referred to as having *short positions*. Selling an option is also known as *writing the option*.

[4] The calculations here ignore commissions paid by the investor.

[5] The calculations here ignore the effect of discounting. Theoretically, the $12,000 should be discounted from the time of exercise to the purchase date, when calculating the profit.

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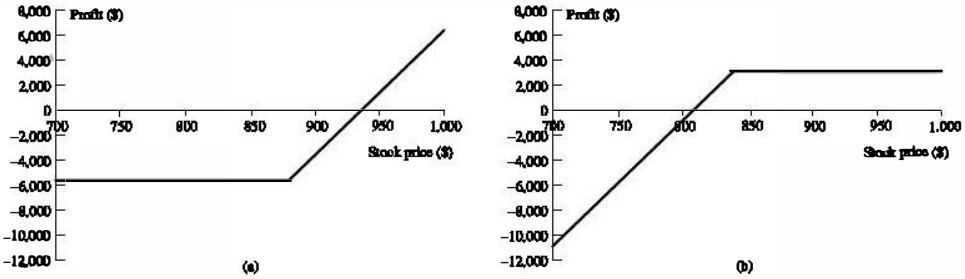

FIGURE 4-3 Net profit per share from (a) purchasing a contract consisting of 100 Google December call options with a strike price of $880 and (b) selling a contract consisting of 100 Google September put options with a strike price of $840.

TYPES OF TRADERS

Derivatives markets have been outstandingly successful. The main reason is that they have attracted many different types of traders and have a great deal of liquidity. When an investor wants to take one side of a contract, there is usually no problem in finding someone who is prepared to take the other side.

Three broad categories of traders can be identified: hedgers, speculators, and arbitrageurs. Hedgers use derivatives to reduce the risk that they face from potential future movements in a market variable. Speculators use them to bet on the future direction of a market variable. Arbitrageurs take offsetting positions in two or more instruments to lock in a profit. As described in Box 4-3, hedge funds have become big users of derivatives for all three purposes.

In the next few sections, we will consider the activities of each type of trader in more detail.

HEDGERS

In this section we illustrate how hedgers can reduce their risks with forward contracts and options.

Hedging Using Forward Contracts

Suppose that it is May 6, 2013, and ImportCo, a company based in the United States, knows that it will have to pay £10 million on August 6, 2013, for goods it has purchased from a British supplier. The USD–GBP exchange rate quotes made by a financial institution are shown in Table 4-1. ImportCo could hedge its foreign exchange risk by buying pounds (GBP) from the financial institution in the 3-month forward market at 1.5538. This would have the effect of fixing the price to be paid to the British exporter at $15,538,000.

Consider next another US company, which we will refer to as ExportCo, that is exporting goods to the United Kingdom and, on May 6, 2013, knows that it will receive £30 million 3 months later. ExportCo can hedge its foreign exchange risk by selling £30 million in the 3-month forward market at an exchange rate of 1.5533. This would have the effect of locking in the US dollars to be realized for the sterling at $46,599,000.

Note that a company might do better if it chooses not to hedge than if it chooses to hedge. Alternatively, it might do worse. Consider ImportCo. If the exchange rate is 1.4000 on August 6 and the company has not hedged, the £10 million that it has to pay will cost $14,000,000, which is less than $15,538,000. On the other hand, if the exchange rate is 1.6000, the £10 million will cost $16,000,000—and the company will wish that it had hedged! The position of ExportCo if it does not hedge is the reverse. If the exchange rate in August proves to be less than 1.5533, the company will wish that it had hedged; if the rate is greater than 1.5533, it will be pleased that it has not done so.

This example illustrates a key aspect of hedging. The purpose of hedging is to reduce risk. There is no guarantee that the outcome with hedging will be better than the outcome without hedging.

Hedging Using Options

Options can also be used for hedging. Consider an investor who in May of a particular year owns 1,000 shares of a particular company. The share price is $28 per share. The investor is concerned about a possible share price decline in the next 2 months and wants protection. The investor could buy ten July put option contracts on the company's stock with a strike price of $27.50. This would give the investor the right to sell a total of 1,000 shares

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BOX 4-3 Hedge Funds

Hedge funds have become major users of derivatives for hedging, speculation, and arbitrage. They are similar to mutual funds in that they invest funds on behalf of clients. However, they accept funds only from financially sophisticated individuals and do not publicly offer their securities. Mutual funds are subject to regulations requiring that the shares be redeemable at any time, that investment policies be disclosed, that the use of leverage be limited, and so on. Hedge funds are relatively free of these regulations. This gives them a great deal of freedom to develop sophisticated, unconventional, and proprietary investment strategies. The fees charged by hedge fund managers are dependent on the fund's performance and are relatively high—typically 1 to 2% of the amount invested plus 20% of the profits. Hedge funds have grown in popularity, with about $2 trillion being invested in them throughout the world. "Funds of funds" have been set up to invest in a portfolio of hedge funds.

The investment strategy followed by a hedge fund manager often involves using derivatives to set up a speculative or arbitrage position. Once the strategy has been defined, the hedge fund manager must:

1. Evaluate the risks to which the fund is exposed
2. Decide which risks are acceptable and which will be hedged
3. Devise strategies (usually involving derivatives) to hedge the unacceptable risks.

Here are some examples of the labels used for hedge funds together with the trading strategies followed:

Long/Short Equities: Purchase securities considered to be undervalued and short those considered to be overvalued in such a way that the exposure to the overall direction of the market is small.

Convertible Arbitrage: Take a long position in a thought-to-be-undervalued convertible bond combined with an actively managed short position in the underlying equity.

Distressed Securities: Buy securities issued by companies in, or close to, bankruptcy.

Emerging Markets: Invest in debt and equity of companies in developing or emerging countries and in the debt of the countries themselves.

Global Macro: Carry out trades that reflect anticipated global macroeconomic trends.

Merger Arbitrage: Trade after a possible merger or acquisition is announced so that a profit is made if the announced deal takes place.

for a price of $27.50. If the quoted option price is $1, then each option contract would cost 100 × $1 = $100 and the total cost of the hedging strategy would be 10 × $100 = $1,000.

The strategy costs $1,000 but guarantees that the shares can be sold for at least $27.50 per share during the life of the option. If the market price of the stock falls below $27.50, the options will be exercised, so that $27,500 is realized for the entire holding. When the cost of the options is taken into account, the amount realized is $26,500. If the market price stays above $27.50, the options are not exercised and expire worthless. However, in this case the value of the holding is always above $27,500 (or above $26,500 when the cost of the options is taken into account). Figure 4-4 shows the net value of the portfolio (after taking the cost of the options into account) as a function of the stock price in 2 months. The dotted line shows the value of the portfolio assuming no hedging.

A Comparison

There is a fundamental difference between the use of forward contracts and options for hedging. Forward contracts are designed to neutralize risk by fixing the price that the hedger will pay or receive for the underlying asset. Option contracts, by contrast, provide insurance. They offer a way for investors to protect themselves

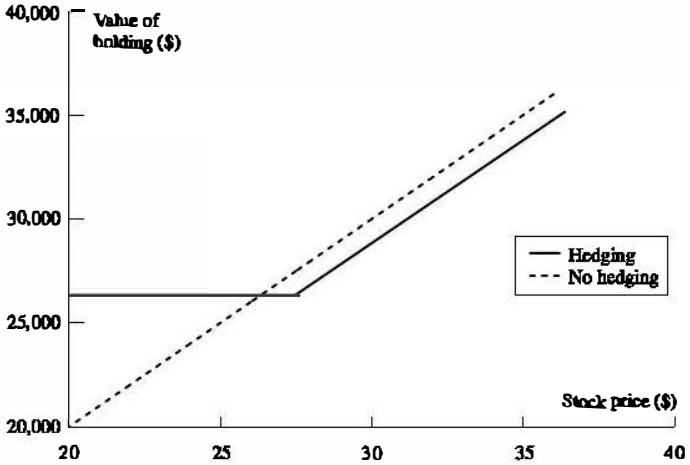

FIGURE 4-4 Value of the stock holding in 2 months with and without hedging.

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against adverse price movements in the future while still allowing them to benefit from favorable price movements. Unlike forwards, options involve the payment of an up-front fee.

SPECULATORS

We now move on to consider how futures and options markets can be used by speculators. Whereas hedgers want to avoid exposure to adverse movements in the price of an asset, speculators wish to take a position in the market. Either they are betting that the price of the asset will go up or they are betting that it will go down.

Speculation Using Futures

Consider a US speculator who in February thinks that the British pound will strengthen relative to the US dollar over the next 2 months and is prepared to back that hunch to the tune of £250,000. One thing the speculator can do is purchase £250,000 in the spot market in the hope that the sterling can be sold later at a higher price. (The sterling once purchased would be kept in an interest-bearing account.) Another possibility is to take a long position in four CME April futures contracts on sterling. (Each futures contract is for the purchase of £62,500.) Table 4-4 summarizes the two alternatives on the assumption that the current exchange rate is 1.5470 dollars per pound and the April futures price is 1.5410 dollars per pound. If the exchange rate turns out to be 1.6000 dollars per pound in April, the futures contract alternative enables the speculator to realize a profit of (1.6000 − 1.5410) × 250,000 = $14,750. The spot market alternative leads to 250,000 units of an asset being purchased for $1.5470 in February and sold for $1.6000 in April, so that a profit of (1.6000 − 1.5470) × 250,000 = $13,250 is made. If the exchange rate falls to 1.5000 dollars per pound, the futures contract gives rise to a (1.5410 − 1.5000) × 250,000 = $10,250 loss, whereas the spot market alternative gives rise to a loss of (1.5470 − 1.5000) × 250,000 = $11,750. The spot market alternative appears to give rise to slightly worse outcomes for both scenarios. But this is because the calculations do not reflect the interest that is earned or paid.

TABLE 4-4 Speculation Using Spot and Futures Contracts. One futures contract is on £62,500. Initial margin on four futures contracts = $20,000.

	Possible Trades	
	Buy £250,000 Spot Price = 1.5470	**Buy 4 Futures Contracts Futures Price = 1.5410**
Investment	$386,750	$20,000
Profit if April spot = 1.6000	$13,250	$14,750
Profit if April spot = 1.5000	−$11,750	−$10,250

What then is the difference between the two alternatives? The first alternative of buying sterling requires an up-front investment of $386,750 (= 250,000 × 1.5470). In contrast, the second alternative requires only a small amount of cash to be deposited by the speculator in what is termed a "margin account". (The operation of margin accounts is explained in Chapter 5.) In Table 4-4, the initial margin requirement is assumed to be $5,000 per contract, or $20,000 in total. The futures market allows the speculator to obtain leverage. With a relatively small initial outlay, the investor is able to take a large speculative position.

Speculation Using Options

Options can also be used for speculation. Suppose that it is October and a speculator considers that a stock is likely to increase in value over the next 2 months. The stock price is currently $20, and a 2-month call option with a $22.50 strike price is currently selling for $1. Table 4-5 illustrates two possible alternatives, assuming that the speculator is willing to invest $2,000. One alternative is to purchase 100 shares; the other involves the purchase of 2,000 call options (i.e., 20 call option contracts). Suppose that the speculator's hunch is correct and the price of the stock rises to $27 by December. The first alternative of buying the stock yields a profit of

$$100 \times (\$27 - \$20) = \$700$$

However, the second alternative is far more profitable. A call option on the stock with a strike price of $22.50 gives a payoff of $4.50, because it enables something worth $27 to be bought for $22.50. The total payoff from the

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TABLE 4-5 Comparison of Profits from Two Alternative Strategies for Using $2,000 to Speculate on a Stock Worth $20 in October

Investor's Strategy	December Stock Price	
	$15	$27
Buy 100 shares	−$500	$700
Buy 2,000 call options	−$2,000	$7,000

2,000 options that are purchased under the second alternative is

$$2{,}000 \times \$4.50 = \$9{,}000$$

Subtracting the original cost of the options yields a net profit of

$$\$9{,}000 - \$2{,}000 = \$7{,}000$$

The options strategy is, therefore, 10 times more profitable than directly buying the stock. Options also give rise to a greater potential loss. Suppose the stock price falls to $15 by December. The first alternative of buying stock yields a loss of

$$100 \times (\$20 - \$15) = \$500$$

Because the call options expire without being exercised, the options strategy would lead to a loss of $2,000—the original amount paid for the options. Figure 4-5 shows the profit or loss from the two strategies as a function of the stock price in 2 months.

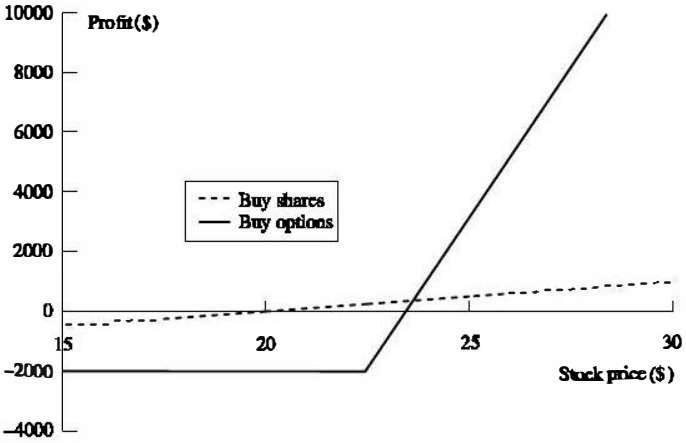

FIGURE 4-5 Profit or loss from two alternative strategies for speculating on a stock currently worth $20.

Options like futures provide a form of leverage. For a given investment, the use of options magnifies the financial consequences. Good outcomes become very good, while bad outcomes result in the whole initial investment being lost.

A Comparison

Futures and options are similar instruments for speculators in that they both provide a way in which a type of leverage can be obtained. However, there is an important difference between the two. When a speculator uses futures, the potential loss as well as the potential gain is very large. When options are used, no matter how bad things get, the speculator's loss is limited to the amount paid for the options.

ARBITRAGEURS

Arbitrageurs are a third important group of participants in futures, forward, and options markets. Arbitrage involves locking in a riskless profit by simultaneously entering into transactions in two or more markets. In later chapters we will see how arbitrage is sometimes possible when the futures price of an asset gets out of line with its spot price. We will also examine how arbitrage can be used in options markets. This section illustrates the concept of arbitrage with a very simple example.

Let us consider a stock that is traded on both the New York Stock Exchange (www.nyse.com) and the London Stock Exchange (www.stockex.co.uk). Suppose that the stock price is $150 in New York and £100 in London at a time when the exchange rate is $1.5300 per pound. An arbitrageur could simultaneously buy 100 shares of the stock in New York and sell them in London to obtain a risk-free profit of

$$100 \times \left[(\$1.53 \times 100) - \$150\right]$$

or $300 in the absence of transactions costs. Transactions costs would probably eliminate the profit for a small investor. However, a large investment bank faces very low transactions costs in both the stock market and the foreign exchange market. It would find the arbitrage opportunity very attractive and would try to take as much advantage of it as possible.

Arbitrage opportunities such as the one just described cannot last for long. As arbitrageurs buy the stock in New York, the forces of supply and demand will cause the dollar price to rise. Similarly, as they sell the stock in London,

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the sterling price will be driven down. Very quickly the two prices will become equivalent at the current exchange rate. Indeed, the existence of profit-hungry arbitrageurs makes it unlikely that a major disparity between the sterling price and the dollar price could ever exist in the first place. Generalizing from this example, we can say that the very existence of arbitrageurs means that in practice only very small arbitrage opportunities are observed in the prices that are quoted in most financial markets. In this book most of the arguments concerning futures prices, forward prices, and the values of option contracts will be based on the assumption that no arbitrage opportunities exist.

DANGERS

Derivatives are very versatile instruments. As we have seen, they can be used for hedging, for speculation, and for arbitrage. It is this very versatility that can cause problems. Sometimes traders who have a mandate to hedge risks or follow an arbitrage strategy become (consciously or unconsciously) speculators. The results can be disastrous. One example of this is provided by the activities of Jérôme Kerviel at Société Général (see Box 4-4).

To avoid the sort of problems Société Général encountered, it is very important for both financial and nonfinancial corporations to set up controls to ensure that derivatives are being used for their intended purpose. Risk limits should be set and the activities of traders should be monitored daily to ensure that these risk limits are adhered to.

Unfortunately, even when traders follow the risk limits that have been specified, big mistakes can happen. Some of the activities of traders in the derivatives market during the period leading up to the start of the credit crisis in July 2007 proved to be much riskier than they were thought to be by the financial institutions they worked for. House prices in the United States had been rising fast. Most people thought that the increases would continue—or, at worst, that house prices would simply level off. Very few were prepared for the steep decline that actually happened. Furthermore, very few were prepared for the high correlation between mortgage default rates in different parts of the country. Some risk managers did express reservations about the exposures of the companies for which they worked to the US real estate market. But, when times are good (or appear to be good), there is an unfortunate tendency to ignore risk managers and this

BOX 4-4 SocGen's Big Loss in 2008

Derivatives are very versatile instruments. They can be used for hedging, speculation, and arbitrage. One of the risks faced by a company that trades derivatives is that an employee who has a mandate to hedge or to look for arbitrage opportunities may become a speculator.

Jérôme Kerviel joined Société Général (SocGen) in 2000 to work in the compliance area. In 2005, he was promoted and became a junior trader in the bank's Delta One products team. He traded equity indices such as the German DAX index, the French CAC 40, and the Euro Stoxx 50. His job was to look for arbitrage opportunities. These might arise if a futures contract on an equity index was trading for a different price on two different exchanges. They might also arise if equity index futures prices were not consistent with the prices of the shares constituting the index. (This type of arbitrage is discussed in Chapter 8.)

Kerviel used his knowledge of the bank's procedures to speculate while giving the appearance of arbitraging. He took big positions in equity indices and created fictitious trades to make it appear that he was hedged. In reality, he had large bets on the direction in which the indices would move. The size of his unhedged position grew over time to tens of billions of euros.

In January 2008, his unauthorized trading was uncovered by SocGen. Over a three-day period, the bank unwound his position for a loss of 4.9 billion euros. This was at the time the biggest loss created by fraudulent activity in the history of finance. (Later in the year, a much bigger loss from Bernard Madoff's Ponzi scheme came to light.)

Rogue trader losses were not unknown at banks prior to 2008. For example, in the 1990s, Nick Leeson, who worked at Barings Bank, had a mandate similar to that of Jérôme Kerviel. His job was to arbitrage between Nikkei 225 futures quotes in Singapore and Osaka. Instead he found a way to make big bets on the direction of the Nikkei 225 using futures and options, losing $1 billion and destroying the 200-year-old bank in the process. In 2002, it was found that John Rusnak at Allied Irish Bank had lost $700 million from unauthorized foreign exchange trading. The lessons from these losses are that it is important to define unambiguous risk limits for traders and then to monitor what they do very carefully to make sure that the limits are adhered to.

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is what happened at many financial institutions during the 2006–2007 period. The key lesson from the credit crisis is that financial institutions should always be dispassionately asking "What can go wrong?", and they should follow that up with the question "If it does go wrong, how much will we lose?"

SUMMARY

One of the exciting developments in finance over the last 40 years has been the growth of derivatives markets. In many situations, both hedgers and speculators find it more attractive to trade a derivative on an asset than to trade the asset itself. Some derivatives are traded on exchanges; others are traded by financial institutions, fund managers, and corporations in the over-the-counter market, or added to new issues of debt and equity securities. Much of this book is concerned with the valuation of derivatives. The aim is to present a unifying framework within which all derivatives—not just options or futures—can be valued.

In this chapter we have taken a first look at forward, futures, and options contracts. A forward or futures contract involves an obligation to buy or sell an asset at a certain time in the future for a certain price. There are two types of options: calls and puts. A call option gives the holder the right to buy an asset by a certain date for a certain price. A put option gives the holder the right to sell an asset by a certain date for a certain price. Forwards, futures, and options trade on a wide range of different underlying assets.

Derivatives have been very successful innovations in capital markets. Three main types of traders can be identified: hedgers, speculators, and arbitrageurs. Hedgers are in the position where they face risk associated with the price of an asset. They use derivatives to reduce or eliminate this risk. Speculators wish to bet on future movements in the price of an asset. They use derivatives to get extra leverage. Arbitrageurs are in business to take advantage of a discrepancy between prices in two different markets. If, for example, they see the futures price of an asset getting out of line with the cash price, they will take offsetting positions in the two markets to lock in a profit.

Further Reading

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Mechanics of Futures Markets

5

Learning Objectives

After completing this reading you should be able to:

- Define and describe the key features of a futures contract, including the asset, the contract price and size, delivery, and limits.
- Explain the convergence of futures and spot prices.
- Describe the rationale for margin requirements and explain how they work.
- Describe the role of a clearinghouse in futures and over-the-counter market transactions.
- Describe the role of collateralization in the over-the-counter market, and compare it to the margining system.
- Identify the differences between a normal and inverted futures market.
- Describe the mechanics of the delivery process and contrast it with cash settlement.
- Evaluate the impact of different trading order types.
- Compare and contrast forward and futures contracts.

Excerpt is Chapter 2 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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In Chapter 4 we explained that both futures and forward contracts are agreements to buy or sell an asset at a future time for a certain price. A futures contract is traded on an exchange, and the contract terms are standardized by that exchange. A forward contract is traded in the over-the-counter market and can be customized if necessary.

This chapter covers the details of how futures markets work. We examine issues such as the specification of contracts, the operation of margin accounts, the organization of exchanges, the regulation of markets, the way in which quotes are made, and the treatment of futures transactions for accounting and tax purposes. We explain how some of the ideas pioneered by futures exchanges are now being adopted by over-the-counter markets.

BACKGROUND

As we saw in Chapter 4, futures contracts are now traded actively all over the world. The Chicago Board of Trade, the Chicago Mercantile Exchange, and the New York Mercantile Exchange have merged to form the CME Group (www.cmegroup.com). Other large exchanges include the Intercontinental Exchange (www.theice.com) which is acquiring NYSE Euronext (www.euronext.com), Eurex (www.eurexchange.com), BM&F BOVESPA (www.bmfbovespa.com.br), and the Tokyo Financial Exchange (www.tfx.co.jp). The appendix at the end of this book provides a more complete list of exchanges.

We examine how a futures contract comes into existence by considering the corn futures contract traded by the CME Group. On June 5 a trader in New York might call a broker with instructions to buy 5,000 bushels of corn for delivery in September of the same year. The broker would immediately issue instructions to a trader to buy (i.e., take a long position in) one September corn contract. (Each corn contract is for the delivery of exactly 5,000 bushels.) At about the same time, another trader in Kansas might instruct a broker to sell 5,000 bushels of corn for September delivery. This broker would then issue instructions to sell (i.e., take a short position in) one corn contract. A price would be determined and the deal would be done. Under the traditional open outcry system, floor traders representing each party would physically meet to determine the price. With electronic trading, a computer would match the traders.

The trader in New York who agreed to buy has a *long futures position* in one contract; the trader in Kansas who agreed to sell has a *short futures position* in one contract. The price agreed to is the current *futures price* for September corn, say 600 cents per bushel. This price, like any other price, is determined by the laws of supply and

BOX 5-1 The Unanticipated Delivery of a Futures Contract

This story (which may well be apocryphal) was told to the author of this book a long time ago by a senior executive of a financial institution. It concerns a new employee of the financial institution who had not previously worked in the financial sector. One of the clients of the financial institution regularly entered into a long futures contract on live cattle for hedging purposes and issued instructions to close out the position on the last day of trading. (Live cattle futures contracts are traded by the CME Group and each contract is on 40,000 pounds of cattle.) The new employee was given responsibility for handling the account.

When the time came to close out a contract the employee noted that the client was long one contract and instructed a trader at the exchange to buy (not sell) one contract. The result of this mistake was that the financial institution ended up with a long position in two live cattle futures contracts. By the time the mistake was spotted trading in the contract had ceased.

The financial institution (not the client) was responsible for the mistake. As a result, it started to look into the details of the delivery arrangements for live cattle futures contracts—something it had never done before. Under the terms of the contract, cattle could be delivered by the party with the short position to a number of different locations in the United States during the delivery month. Because it was long, the financial institution could do nothing but wait for a party with a short position to issue a *notice of intention to deliver* to the exchange and for the exchange to assign that notice to the financial institution.

It eventually received a notice from the exchange and found that it would receive live cattle at a location 2,000 miles away the following Tuesday. The new employee was sent to the location to handle things. It turned out that the location had a cattle auction every Tuesday. The party with the short position that was making delivery bought cattle at the auction and then immediately delivered them. Unfortunately the cattle could not be resold until the next cattle auction the following Tuesday. The employee was therefore faced with the problem of making arrangements for the cattle to be housed and fed for a week. This was a great start to a first job in the financial sector!

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demand. If, at a particular time, more traders wish to sell rather than buy September corn, the price will go down. New buyers then enter the market so that a balance between buyers and sellers is maintained. If more traders wish to buy rather than sell September corn, the price goes up. New sellers then enter the market and a balance between buyers and sellers is maintained.

Closing Out Positions

The vast majority of futures contracts do not lead to delivery. The reason is that most traders choose to close out their positions prior to the delivery period specified in the contract. Closing out a position means entering into the opposite trade to the original one. For example, the New York trader who bought a September corn futures contract on June 5 can close out the position by selling (i.e., shorting) one September corn futures contract on, say, July 20. The Kansas trader who sold (i.e., shorted) a September contract on June 5 can close out the position by buying one September contract on, say, August 25. In each case, the trader's total gain or loss is determined by the change in the futures price between June 5 and the day when the contract is closed out.

Delivery is so unusual that traders sometimes forget how the delivery process works (see Box 5-1). Nevertheless, we will review delivery procedures later in this chapter. This is because it is the possibility of final delivery that ties the futures price to the spot price.[1]

SPECIFICATION OF A FUTURES CONTRACT

When developing a new contract, the exchange must specify in some detail the exact nature of the agreement between the two parties. In particular, it must specify the asset, the contract size (exactly how much of the asset will be delivered under one contract), where delivery can be made, and when delivery can be made.

Sometimes alternatives are specified for the grade of the asset that will be delivered or for the delivery locations. As a general rule, it is the party with the short position (the party that has agreed to sell the asset) that chooses what will happen when alternatives are specified by the exchange.[2] When the party with the short position is ready to deliver, it files a *notice of intention to deliver* with the exchange. This notice indicates any selections it has made with respect to the grade of asset that will be delivered and the delivery location.

The Asset

When the asset is a commodity, there may be quite a variation in the quality of what is available in the marketplace. When the asset is specified, it is therefore important that the exchange stipulate the grade or grades of the commodity that are acceptable. The Intercontinental Exchange (ICE) has specified the asset in its orange juice futures contract as frozen concentrates that are US Grade A with Brix value of not less than 62.5 degrees.

For some commodities a range of grades can be delivered, but the price received depends on the grade chosen. For example, in the CME Group's corn futures contract, the standard grade is "No. 2 Yellow," but substitutions are allowed with the price being adjusted in a way established by the exchange. No. 1 Yellow is deliverable for 1.5 cents per bushel more than No. 2 Yellow. No. 3 Yellow is deliverable for 1.5 cents per bushel less than No. 2 Yellow.

The financial assets in futures contracts are generally well defined and unambiguous. For example, there is no need to specify the grade of a Japanese yen. However, there are some interesting features of the Treasury bond and Treasury note futures contracts traded on the Chicago Board of Trade. The underlying asset in the Treasury bond contract is any US Treasury bond that has a maturity between 15 and 25 years. In the Treasury note futures contract, the underlying asset is any Treasury note with a maturity of between 6.5 and 10 years. In both cases, the exchange has a formula for adjusting the price received according to the coupon and maturity date of the bond delivered. This is discussed in Chapter 9.

The Contract Size

The contract size specifies the amount of the asset that has to be delivered under one contract. This is an important decision for the exchange. If the contract size is too large, many investors who wish to hedge relatively small

[1] As mentioned in Chapter 4, the spot price is the price for almost immediate delivery.

[2] There are exceptions. As pointed out by J. E. Newsome, G. H. F. Wang, M. E. Boyd, and M. J. Fuller in "Contract Modifications and the Basic Behavior of Live Cattle Futures," *Journal of Futures Markets*, 24, 6 (2004), 557–90, the CME gave the buyer some delivery options in live cattle futures in 1995.

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exposures or who wish to take relatively small speculative positions will be unable to use the exchange. On the other hand, if the contract size is too small, trading may be expensive as there is a cost associated with each contract traded.

The correct size for a contract clearly depends on the likely user. Whereas the value of what is delivered under a futures contract on an agricultural product might be $10,000 to $20,000, it is much higher for some financial futures. For example, under the Treasury bond futures contract traded by the CME Group, instruments with a face value of $100,000 are delivered.

In some cases exchanges have introduced "mini" contracts to attract smaller investors. For example, the CME Group's Mini Nasdaq 100 contract is on 20 times the Nasdaq 100 index, whereas the regular contract is on 100 times the index. (We will cover futures on indices more fully in Chapter 6.)

Delivery Arrangements

The place where delivery will be made must be specified by the exchange. This is particularly important for commodities that involve significant transportation costs. In the case of the ICE frozen concentrate orange juice contract, delivery is to exchange-licensed warehouses in Florida, New Jersey, or Delaware.

When alternative delivery locations are specified, the price received by the party with the short position is sometimes adjusted according to the location chosen by that party. The price tends to be higher for delivery locations that are relatively far from the main sources of the commodity.

Delivery Months

A futures contract is referred to by its delivery month. The exchange must specify the precise period during the month when delivery can be made. For many futures contracts, the delivery period is the whole month.

The delivery months vary from contract to contract and are chosen by the exchange to meet the needs of market participants. For example, corn futures traded by the CME Group have delivery months of March, May, July, September, and December. At any given time, contracts trade for the closest delivery month and a number of subsequent delivery months. The exchange specifies when trading in a particular month's contract will begin. The exchange also specifies the last day on which trading can take place for a given contract. Trading generally ceases a few days before the last day on which delivery can be made.

Price Quotes

The exchange defines how prices will be quoted. For example, in the US crude oil futures contract, prices are quoted in dollars and cents. Treasury bond and Treasury note futures prices are quoted in dollars and thirty-seconds of a dollar.

Price Limits and Position Limits

For most contracts, daily price movement limits are specified by the exchange. If in a day the price moves down from the previous day's close by an amount equal to the daily price limit, the contract is said to be *limit down.* If it moves up by the limit, it is said to be *limit up.* A *limit move* is a move in either direction equal to the daily price limit. Normally, trading ceases for the day once the contract is limit up or limit down. However, in some instances the exchange has the authority to step in and change the limits.

The purpose of daily price limits is to prevent large price movements from occurring because of speculative excesses. However, limits can become an artificial barrier to trading when the price of the underlying commodity is advancing or declining rapidly. Whether price limits are, on balance, good for futures markets is controversial.

Position limits are the maximum number of contracts that a speculator may hold. The purpose of these limits is to prevent speculators from exercising undue influence on the market.

CONVERGENCE OF FUTURES PRICE TO SPOT PRICE

As the delivery period for a futures contract is approached, the futures price converges to the spot price of the underlying asset. When the delivery period is reached, the futures price equals—or is very close to—the spot price.

To see why this is so, we first suppose that the futures price is above the spot price during the delivery period. Traders then have a clear arbitrage opportunity:

1. Sell (i.e., short) a futures contract
2. Buy the asset
3. Make delivery.

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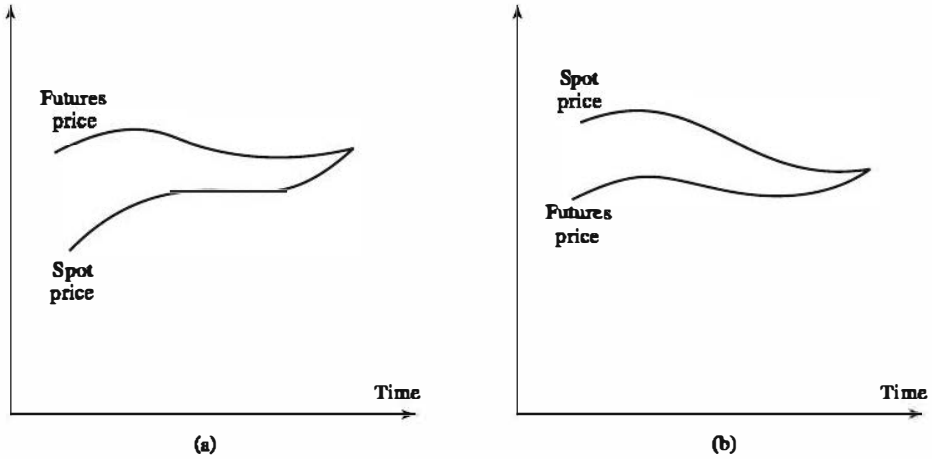

FIGURE 5-1 Relationship between futures price and spot price as the delivery period is approached: (a) Futures price above spot price; (b) futures price below spot price.

These steps are certain to lead to a profit equal to the amount by which the futures price exceeds the spot price. As traders exploit this arbitrage opportunity, the futures price will fall. Suppose next that the futures price is below the spot price during the delivery period. Companies interested in acquiring the asset will find it attractive to enter into a long futures contract and then wait for delivery to be made. As they do so, the futures price will tend to rise.

The result is that the futures price is very close to the spot price during the delivery period. Figure 5-1 illustrates the convergence of the futures price to the spot price. In Figure 5-1a the futures price is above the spot price prior to the delivery period. In Figure 5-1b the futures price is below the spot price prior to the delivery period. The circumstances under which these two patterns are observed are discussed in Chapter 8.

THE OPERATION OF MARGIN ACCOUNTS

If two investors get in touch with each other directly and agree to trade an asset in the future for a certain price, there are obvious risks. One of the investors may regret the deal and try to back out. Alternatively, the investor simply may not have the financial resources to honor the agreement. One of the key roles of the exchange is to organize trading so that contract defaults are avoided. This is where margin accounts come in.

Daily Settlement

To illustrate how margin accounts work, we consider an investor who contacts his or her broker to buy two December gold futures contracts on the COMEX division of the New York Mercantile Exchange (NYMEX), which is part of the CME Group. We suppose that the current futures price is $1,450 per ounce. Because the contract size is 100 ounces, the investor has contracted to buy a total of 200 ounces at this price. The broker will require the investor to deposit funds in a margin account. The amount that must be deposited at the time the contract is entered into is known as the *initial margin*. We suppose this is $6,000 per contract, or $12,000 in total. At the end of each trading day, the margin account is adjusted to reflect the investor's gain or loss. This practice is referred to as *daily settlement* or *marking to market*.

Suppose, for example, that by the end of the first day the futures price has dropped by $9 from $1,450 to $1,441. The investor has a loss of $1,800 (= 200 × $9), because the 200 ounces of December gold, which the investor contracted to buy at $1,450, can now be sold for only $1,441. The balance in the margin account would therefore be reduced by $1,800 to $10,200. Similarly, if the price of December gold rose to $1,459 by the end of the first day, the balance in the margin account would be increased by $1,800 to $13,800. A trade is first settled at the close of the day on which it takes place. It is then settled at the close of trading on each subsequent day.

Note that daily settlement is not merely an arrangement between broker and client. When there is a decrease in the futures price so that the margin account of an investor with a long position is reduced by $1,800, the investor's broker has to pay the exchange clearing house $1,800 and this money is passed on to the broker of an investor with a short position. Similarly, when there is an increase in the futures price, brokers for parties with short positions pay money to the exchange clearing house and brokers for parties with long positions receive money from the exchange clearing house. Later we will examine in more detail the mechanism by which this happens.

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The investor is entitled to withdraw any balance in the margin account in excess of the initial margin. To ensure that the balance in the margin account never becomes negative a *maintenance margin*, which is somewhat lower than the initial margin, is set. If the balance in the margin account falls below the maintenance margin, the investor receives a margin call and is expected to top up the margin account to the initial margin level by the end of the next day. The extra funds deposited are known as a *variation margin*. If the investor does not provide the variation margin, the broker closes out the position. In the case of the investor considered earlier, closing out the position would involve neutralizing the existing contract by selling 200 ounces of gold for delivery in December.

Table 5-1 illustrates the operation of the margin account for one possible sequence of futures prices in the case of the investor considered earlier. The maintenance margin is assumed to be $4,500 per contract, or $9,000 in total. On Day 7, the balance in the margin account falls $1,020 below the maintenance margin level. This drop triggers a margin call from the broker for an additional $4,020 to bring the account balance up to the initial margin level of $12,000. It is assumed that the investor provides this margin by the close of trading on Day 8. On Day 11, the balance in the margin account again falls below the maintenance margin level, and a margin call for $3,780 is sent out. The investor provides this margin by the close of trading on Day 12. On Day 16, the investor decides to close

TABLE 5-1 Operation of Margin Account for a Long Position in Two Gold Futures Contracts. The initial margin is $6,000 per contract, or $12,000 in total; the maintenance margin is $4,500 per contract, or $9,000 in total. The contract is entered into on Day 1 at $1,450 and closed out on Day 16 at $1,426.90.

Day	Trade Price ($)	Settlement Price ($)	Daily Gain ($)	Cumulative Gain ($)	Margin Account Balance ($)	Margin Call ($)
1	1,450.00				12,000	
1		1,441.00	−1,800	−1,800	10,200	
2		1,438.30	−540	−2,340	9,660	
3		1,444.60	1,260	−1,080	10,920	
4		1,441.30	−660	−1,740	10,260	
5		1,440.10	−240	−1,980	10,020	
6		1,436.20	−780	−2,760	9,240	
7		1,429.90	−1,260	−4,020	7,980	4,020
8		1,430.80	180	−3,840	12,180	
9		1,425.40	−1,080	−4,920	11,100	
10		1,428.10	540	−4,380	11,640	
11		1,411.00	−3,420	−7,800	8,220	3,780
12		1,411.00	0	−7,800	12,000	
13		1,414.30	660	−7,140	12,660	
14		1,416.10	360	−6,780	13,020	
15		1,423.00	1,380	−5,400	14,400	
16	1,426.90		780	−4,620	15,180	

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out the position by selling two contracts. The futures price on that day is $1,426.90, and the investor has a cumulative loss of $4,620. Note that the investor has excess margin on Days 8, 13, 14, and 15. It is assumed that the excess is not withdrawn.

Further Details

Most brokers pay investors interest on the balance in a margin account. The balance in the account does not, therefore, represent a true cost, provided that the interest rate is competitive with what could be earned elsewhere. To satisfy the initial margin requirements, but not subsequent margin calls, an investor can usually deposit securities with the broker. Treasury bills are usually accepted in lieu of cash at about 90% of their face value. Shares are also sometimes accepted in lieu of cash, but at about 50% of their market value.

Whereas a forward contract is settled at the end of its life, a futures contract is, as we have seen, settled daily. At the end of each day, the investor's gain (loss) is added to (subtracted from) the margin account, bringing the value of the contract back to zero. A futures contract is in effect closed out and rewritten at a new price each day.

Minimum levels for the initial and maintenance margin are set by the exchange clearing house. Individual brokers may require greater margins from their clients than the minimum levels specified by the exchange clearing house. Minimum margin levels are determined by the variability of the price of the underlying asset and are revised when necessary. The higher the variability, the higher the margin levels. The maintenance margin is usually about 75% of the initial margin.

Margin requirements may depend on the objectives of the trader. A bona fide hedger, such as a company that produces the commodity on which the futures contract is written, is often subject to lower margin requirements than a speculator. The reason is that there is deemed to be less risk of default. Day trades and spread transactions often give rise to lower margin requirements than do hedge transactions. In a *day trade* the trader announces to the broker an intent to close out the position in the same day. In a *spread transaction* the trader simultaneously buys (i.e., takes a long position in) a contract on an asset for one maturity month and sells (i.e., takes a short position in) a contract on the same asset for another maturity month.

Note that margin requirements are the same on short futures positions as they are on long futures positions. It is just as easy to take a short futures position as it is to take a long one. The spot market does not have this symmetry. Taking a long position in the spot market involves buying the asset for immediate delivery and presents no problems. Taking a short position involves selling an asset that you do not own. This is a more complex transaction that may or may not be possible in a particular market. It is discussed further in Chapter 8.

The Clearing House and Its Members

A *clearing house* acts as an intermediary in futures transactions. It guarantees the performance of the parties to each transaction. The clearing house has a number of members. Brokers who are not members themselves must channel their business through a member and post margin with the member. The main task of the clearing house is to keep track of all the transactions that take place during a day, so that it can calculate the net position of each of its members.

The clearing house member is required to provide initial margin (sometimes referred to as clearing margin) reflecting the total number of contracts that are being cleared. There is no maintenance margin applicable to the clearing house member. Each day the transactions being handled by the clearing house member are settled through the clearing house. If in total the transactions have lost money, the member is required to provide variation margin to the exchange clearing house; if there has been a gain on the transactions, the member receives variation margin from the clearing house.

In determining initial margin, the number of contracts outstanding is usually calculated on a net basis. This means that short positions the clearing house member is handling for clients are offset against long positions. Suppose, for example, that the clearing house member has two clients: one with a long position in 20 contracts, the other with a short position in 15 contracts. The initial margin would be calculated on the basis of 5 contracts. Clearing house members are required to contribute to a guaranty fund. This may be used by the clearing house in the event that a member fails to provide variation margin when required to do so, and there are losses when the member's positions are closed out.

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Credit Risk

The whole purpose of the margining system is to ensure that funds are available to pay traders when they make a profit. Overall the system has been very successful. Traders entering into contracts at major exchanges have always had their contracts honored. Futures markets were tested on October 19, 1987, when the S&P 500 index declined by over 20% and traders with long positions in S&P 500 futures found they had negative margin balances. Traders who did not meet margin calls were closed out but still owed their brokers money. Some did not pay and as a result some brokers went bankrupt because, without their clients' money, they were unable to meet margin calls on contracts they entered into on behalf of their clients. However, the clearing houses had sufficient funds to ensure that everyone who had a short futures position on the S&P 500 got paid off.

OTC MARKETS

Over-the-counter (OTC) markets, introduced in Chapter 4, are markets where companies agree to derivatives transactions without involving an exchange. Credit risk has traditionally been a feature of OTC derivatives markets. Consider two companies, A and B, that have entered into a number of derivatives transactions. If A defaults when the net value of the outstanding transactions to B is positive, a loss is likely to be taken by B. Similarly, if B defaults when the net value of outstanding transactions to A is positive, a loss is likely to be taken by company A. In an attempt to reduce credit risk, the OTC market has borrowed some ideas from exchange-traded markets. We now discuss this.

Central Counterparties

We briefly mentioned CCPs in Chapter 4. These are clearing houses for standard OTC transactions that perform much the same role as exchange clearing houses. Members of the CCP, similarly to members of an exchange clearing house, have to provide both initial margin and daily variation margin. Like members of an exchange clearing house, they are also required to contribute to a guaranty fund.

Once an OTC derivative transaction has been agreed between two parties A and B, it can be presented to a CCP. Assuming the CCP accepts the transaction, it becomes the counterparty to both A and B. (This is similar to the way the clearing house for a futures exchange becomes the counterparty to the two sides of a futures trade.) For example, if the transaction is a forward contract where A has agreed to buy an asset from B in one year for a certain price, the clearing house agrees to

1. Buy the asset from B in one year for the agreed price, and
2. Sell the asset to A in one year for the agreed price.

It takes on the credit risk of both A and B.

All members of the CCP are required to provide initial margin to the CCP. Transactions are valued daily and there are daily variation margin payments to or from the member. If an OTC market participant is not itself a member of a CCP, it can arrange to clear its trades through a CCP member. It will then have to provide margin to the CCP. Its relationship with the CCP member is similar to the relationship between a broker and a futures exchange clearing house member.

Following the credit crisis that started in 2007, regulators have become more concerned about systemic risk (see Box 5-2). One result of this, mentioned in Chapter 4, has been legislation requiring that most standard OTC transactions between financial institutions be handled by CCPs.

Bilateral Clearing

Those OTC transactions that are not cleared through CCPs are cleared bilaterally. In the bilaterally-cleared OTC market, two companies A and B usually enter into a master agreement covering all their trades.[3] This agreement often includes an annex, referred to as the credit support annex or CSA, requiring A or B, or both, to provide collateral. The collateral is similar to the margin required by exchange clearing houses or CCPs from their members.

Collateral agreements in CSAs usually require transactions to be valued each day. A simple two-way agreement between companies A and B might work as follows. If, from one day to the next, the transactions between A and B increase in value to A by X (and therefore decrease in value to B by X), B is required to provide

[3] The most common such agreement is an International Swaps and Derivatives Association (ISDA) Master Agreement.

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collateral worth X to A. If the reverse happens and the transactions increase in value to B by X (and decrease in value to A by X), A is required to provide collateral worth X to B. (To use the terminology of exchange-traded markets, X is the variation margin provided.)

It has traditionally been relatively rare for a CSA to require initial margin. This is changing. New regulations introduced in 2012 require both initial margin and variation margin to be provided for bilaterally cleared transactions between financial institutions.[4] The initial margin will typically be segregated from other funds and posted with a third party.

Collateral significantly reduces credit risk in the bilaterally cleared OTC market (and will do so even more when the new rules requiring initial margin for transactions between financial institutions come into force). Collateral agreements were used by hedge fund Long-Term Capital Management (LTCM) for its bilaterally cleared derivatives 1990s. The agreements allowed LTCM to be highly levered. They did provide credit protection, but as described in Box 5-2, the high leverage left the hedge fund exposed to other risks.

Figure 5-2 illustrates the way bilateral and central clearing work. (It makes the simplifying assumption that there are only eight market participants and one CCP). Under bilateral clearing there are many different agreements between market participants, as indicated in Figure 5-2a. If all OTC contracts were cleared through a single CCP, we would move to the situation shown in Figure 5-2b. In practice, because not all OTC transactions are routed through CCPs and there is more than one CCP, the market has elements of both Figure 5-2a and Figure 5-2b.[5]

BOX 5-2 Long-Term Capital Management's Big Loss

Long-Term Capital Management (LTCM), a hedge fund formed in the mid-1990s, always collateralized its bilaterally cleared transactions. The hedge fund's investment strategy was known as convergence arbitrage. A very simple example of what it might do is the following. It would find two bonds, X and Y, issued by the same company that promised the same payoffs, with X being less liquid (i.e., less actively traded) than Y. The market places a value on liquidity. As a result the price of X would be less than the price of Y. LTCM would buy X, short Y, and wait, expecting the prices of the two bonds to converge at some future time.

When interest rates increased, the company expected both bonds to move down in price by about the same amount, so that the collateral it paid on bond X would be about the same as the collateral it received on bond Y. Similarly, when interest rates decreased, LTCM expected both bonds to move up in price by about the same amount, so that the collateral it received on bond X would be about the same as the collateral it paid on bond Y. It therefore expected that there would be no significant outflow of funds as a result of its collateralization agreements.

In August 1998, Russia defaulted on its debt and this led to what is termed a "flight to quality" in capital markets. One result was that investors valued liquid instruments more highly than usual and the spreads between the prices of the liquid and illiquid instruments in LTCM's portfolio increased dramatically. The prices of the bonds LTCM had bought went down and the prices of those it had shorted increased. It was required to post collateral on both. The company experienced difficulties because it was highly leveraged. Positions had to be closed out and LTCM lost about $4 billion. If the company had been less highly leveraged, it would probably have been able to survive the flight to quality and could have waited for the prices of the liquid and illiquid bonds to move back closer to each other.

Futures Trades vs. OTC Trades

Regardless of how transactions are cleared, initial margin when provided in the form of cash usually earns interest. The daily variation margin provided by clearing house members for futures contracts does not earn interest. This is because the variation margin constitutes the daily settlement. Transactions in the OTC market, whether cleared through CCPs or cleared bilaterally, are usually not settled

[4] For both this regulation and the regulation requiring standard transactions between financial institutions to be cleared through CCPs, "financial institutions" include banks, insurance companies, pension funds, and hedge funds. Transactions with non-financial institutions and some foreign exchange transactions are exempt from the regulations.

[5] The impact of CCPs on credit risk depends on the number of CCPs and proportions of all trades that are cleared through them. See D. Duffie and H. Zhu, "Does a Central Clearing Counterparty Reduce Counterparty Risk," *Review of Asset Pricing Studies*, 1 (2011): 74–95.

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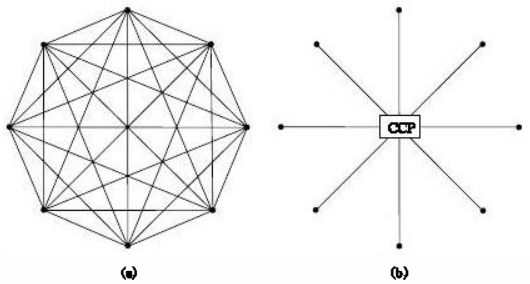

FIGURE 5-2 (a) The traditional way in which OTC markets have operated: a series of bilateral agreements between market participants; (b) how OTC markets would operate with a single central counterparty (CCP) acting as a clearing house.

daily. For this reason, the daily variation margin that is provided by the member of a CCP or, as a result of a CSA, earns interest when it is in the form of cash.

Securities can often be used to satisfy margin/collateral requirements.[5] The market value of the securities is reduced by a certain amount to determine their value for margin purposes. This reduction is known as a *haircut*.

MARKET QUOTES

Futures quotes are available from exchanges and several online sources. Table 5-2 is constructed from quotes provided by the CME Group for a number of different commodities at about noon on May 14, 2013. Similar quotes for index, currency, and interest rate futures are given in Chapters 6, 8, and 9, respectively.

The asset underlying the futures contract, the contract size, and the way the price is quoted are shown at the top of each section of Table 5-2. The first asset is gold. The contract size is 100 ounces and the price is quoted as dollars per ounce. The maturity month of the contract is indicated in the first column of the table.

Prices

The first three numbers in each row of Table 5-2 show the opening price, the highest price in trading so far during the day, and the lowest price in trading so far during the day. The opening price is representative of the prices at which contracts were trading immediately after the start of trading on May 14, 2013. For the June 2013 gold contract, the opening price on May 14, 2013, was $1,429.5 per ounce. The highest price during the day was $1,444.9 per ounce and the lowest price during the day was $1,419.7 per ounce.

Settlement Price

The *settlement price* is the price used for calculating daily gains and losses and margin requirements. It is usually calculated as the price at which the contract traded immediately before the end of a day's trading session. The fourth number in Table 5-2 shows the settlement price the previous day (i.e., May 13, 2013). The fifth number shows the most recent trading price, and the sixth number shows the price change from the previous day's settlement price. In the case of the June 2013 gold contract, the previous day's settlement price was $1,434.3. The most recent trade was at $1,425.3, $9.0 lower than the previous day's settlement price. If $1,425.3 proved to be the settlement price on May 14, 2013, the margin account of a trader with a long position in one contract would lose $900 on May 14 and the margin account of a trader with a short position would gain this amount on May 14.

Trading Volume and Open Interest

The final column of Table 5-2 shows the *trading volume*. The trading volume is the number of contracts traded in a day. It can be contrasted with the *open interest*, which is the number of contracts outstanding, that is, the number of long positions or, equivalently, the number of short positions.

If there is a large amount of trading by day traders (i.e., traders who enter into a position and close it out on the same day), the volume of trading in a day can be greater than either the beginning-of-day or end-of-day open interest.

Patterns of Futures

Futures prices can show a number of different patterns. In Table 5-2, gold, wheat, and live cattle settlement futures prices are an increasing function of the maturity of the contract. This is known as a *normal market*. The situation where settlement futures prices decline

[5] As already mentioned, the variation margin for futures contracts must be provided in the form of cash.

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TABLE 5-2 Futures Quotes for a Selection of CME Group Contracts on Commodities on May 14, 2013

	Open	High	Low	Prior Settlement	Last Trade	Change	Volume
Gold 100 oz, $ per oz							
June 2013	1429.5	1444.9	1419.7	1434.3	1425.3	−9.0	147,943
Aug. 2013	1431.5	1446.0	1421.3	1435.6	1426.7	−8.9	13,469
Oct. 2013	1440.0	1443.3	1424.9	1436.6	1427.8	−8.8	3,522
Dec. 2013	1439.9	1447.1	1423.6	1437.7	1429.5	−8.2	4,353
June 2014	1441.9	1441.9	1441.9	1440.9	1441.9	+1.0	291
Crude Oil 1000 Barrels, $ per Barrel							
June 2013	94.93	95.66	94.50	95.17	94.72	−0.45	162,901
Aug. 2013	95.24	95.92	94.81	95.43	95.01	−0.42	37,830
Dec. 2013	93.77	94.37	93.39	93.89	93.60	−0.29	27,179
Dec. 2014	89.98	90.09	89.40	89.71	89.62	−0.09	9,606
Dec. 2015	86.99	87.33	86.94	86.99	86.94	−0.05	2,181
Corn 5000 Bushels, Cents per Bushel							
July 2013	655.00	657.75	646.50	655.50	652.50	−3.00	48,615
Sept. 2013	568.50	573.25	564.75	568.50	570.00	+1.50	19,388
Dec. 2013	540.00	544.00	535.25	539.25	539.50	+0.25	43,290
Mar. 2014	549.25	553.50	545.50	549.25	549.25	0.00	2,638
May 2014	557.00	561.25	553.50	557.00	557.00	0.00	1,980
July 2014	565.00	568.50	560.25	564.25	563.50	−0.75	1,086
Soybeans 5000 Bushel, Cents per Bushel							
July 2013	1418.75	1426.00	1405.00	1419.25	1418.00	−1.25	56,425
Aug. 2013	1345.00	1351.25	1332.25	1345.00	1345.75	+0.75	4,232
Sept. 2013	1263.75	1270.00	1255.50	1263.00	1268.00	+5.00	1,478
Nov. 2013	1209.75	1218.00	1203.25	1209.75	1216.75	+7.00	29,890
Jan. 2014	1217.50	1225.00	1210.75	1217.50	1224.25	+6.75	4,488
Mar. 2014	1227.50	1230.75	1216.75	1223.50	1230.25	+6.75	1,107
Wheat 5000 Bushel, Cents per Bushel							
July 2013	710.00	716.75	706.75	709.75	710.00	+0.25	30,994
Sept. 2013	718.00	724.75	715.50	718.00	718.50	+0.50	10,608
Dec. 2013	735.00	741.25	732.25	735.00	735.00	0.00	11,305
Mar. 2014	752.50	757.50	749.50	752.50	752.50	0.00	1,321
Live Cattle 40,000 lbs, Cents per lb							
June 2013	120.550	121.175	120.400	120.575	120.875	+0.300	17,628
Aug. 2013	120.700	121.250	120.200	120.875	120.500	−0.375	13,922
Oct. 2013	124.100	124.400	123.375	124.125	123.800	−0.325	2,704
Dec. 2013	125.500	126.025	125.050	125.650	125.475	−0.175	1,107

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with maturity is referred as an *inverted market*.[7] Commodities such as crude oil, corn, and soybeans showed patterns that were partly normal and partly inverted on May 14, 2013.

DELIVERY

As mentioned earlier in this chapter, very few of the futures contracts that are entered into lead to delivery of the underlying asset. Most are closed out early. Nevertheless, it is the possibility of eventual delivery that determines the futures price. An understanding of delivery procedures is therefore important.

The period during which delivery can be made is defined by the exchange and varies from contract to contract. The decision on when to deliver is made by the party with the short position, whom we shall refer to as investor A. When investor A decides to deliver, investor A's broker issues a notice of intention to deliver to the exchange clearing house. This notice states how many contracts will be delivered and, in the case of commodities, also specifies where delivery will be made and what grade will be delivered. The exchange then chooses a party with a long position to accept delivery.

Suppose that the party on the other side of investor A's futures contract when it was entered into was investor B. It is important to realize that there is no reason to expect that it will be investor B who takes delivery. Investor B may well have closed out his or her position by trading with investor C, investor C may have closed out his or her position by trading with investor D, and so on. The usual rule chosen by the exchange is to pass the notice of intention to deliver on to the party with the oldest outstanding long position. Parties with long positions must accept delivery notices. However, if the notices are transferable, long investors have a short period of time, usually half an hour, to find another party with a long position that is prepared to take delivery in place of them.

In the case of a commodity, taking delivery usually means accepting a warehouse receipt in return for immediate payment. The party taking delivery is then responsible for all warehousing costs. In the case of livestock futures, there may be costs associated with feeding and looking after the animals (see Box 5-1). In the case of financial futures, delivery is usually made by wire transfer. For all contracts, the price paid is usually the most recent settlement price. If specified by the exchange, this price is adjusted for grade, location of delivery, and so on. The whole delivery procedure from the issuance of the notice of intention to deliver to the delivery itself generally takes about two to three days.

There are three critical days for a contract. These are the first notice day, the last notice day, and the last trading day. The *first notice day* is the first day on which a notice of intention to make delivery can be submitted to the exchange. The *last notice day* is the last such day. The *last trading day* is generally a few days before the last notice day. To avoid the risk of having to take delivery, an investor with a long position should close out his or her contracts prior to the first notice day.

Cash Settlement

Some financial futures, such as those on stock indices discussed in Chapter 6, are settled in cash because it is inconvenient or impossible to deliver the underlying asset. In the case of the futures contract on the S&P 500, for example, delivering the underlying asset would involve delivering a portfolio of 500 stocks. When a contract is settled in cash, all outstanding contracts are declared closed on a predetermined day. The final settlement price is set equal to the spot price of the underlying asset at either the open or close of trading on that day. For example, in the S&P 500 futures contract traded by the CME Group, the predetermined day is the third Friday of the delivery month and final settlement is at the opening price.

TYPES OF TRADERS AND TYPES OF ORDERS

There are two main types of traders executing trades: *futures commission merchants* (FCMs) and *locals*. FCMs are following the instructions of their clients and charge a commission for doing so; locals are trading on their own account.

[7] The term *contango* is sometimes used to describe the situation where the futures price is an increasing function of maturity and the term *backwardation* is sometimes used to describe the situation where the futures price is a decreasing function of the maturity of the contract. Strictly speaking, as will be explained in Chapter 8, these terms refer to whether the price of the underlying asset is expected to increase or decrease over time.

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Individuals taking positions, whether locals or the clients of FCMs, can be categorized as hedgers, speculators, or arbitrageurs, as discussed in Chapter 4. Speculators can be classified as scalpers, day traders, or position traders. *Scalpers* are watching for very short-term trends and attempt to profit from small changes in the contract price. They usually hold their positions for only a few minutes. *Day traders* hold their positions for less than one trading day. They are unwilling to take the risk that adverse news will occur overnight. *Position traders* hold their positions for much longer periods of time. They hope to make significant profits from major movements in the markets.

Orders

The simplest type of order placed with a broker is a *market order.* It is a request that a trade be carried out immediately at the best price available in the market. However, there are many other types of orders. We will consider those that are more commonly used.

A *limit order* specifies a particular price. The order can be executed only at this price or at one more favorable to the investor. Thus, if the limit price is $30 for an investor wanting to buy, the order will be executed only at a price of $30 or less. There is, of course, no guarantee that the order will be executed at all, because the limit price may never be reached.

A *stop order* or *stop-loss order* also specifies a particular price. The order is executed at the best available price once a bid or offer is made at that particular price or a less-favorable price. Suppose a stop order to sell at $30 is issued when the market price is $35. It becomes an order to sell when and if the price falls to $30. In effect, a stop order becomes a market order as soon as the specified price has been hit. The purpose of a stop order is usually to close out a position if unfavorable price movements take place. It limits the loss that can be incurred.

A *stop–limit order* is a combination of a stop order and a limit order. The order becomes a limit order as soon as a bid or offer is made at a price equal to or less favorable than the stop price. Two prices must be specified in a stop–limit order: the stop price and the limit price. Suppose that at the time the market price is $35, a stop–limit order to buy is issued with a stop price of $40 and a limit price of $41. As soon as there is a bid or offer at $40, the stop–limit becomes a limit order at $41. If the stop price and the limit price are the same, the order is sometimes called a *stop-and-limit order.*

A *market-if-touched* (MIT) *order* is executed at the best available price after a trade occurs at a specified price or at a price more favorable than the specified price. In effect, an MIT becomes a market order once the specified price has been hit. An MIT is also known as a *board order.* Consider an investor who has a long position in a futures contract and is issuing instructions that would lead to closing out the contract. A stop order is designed to place a limit on the loss that can occur in the event of unfavorable price movements. By contrast, a market-if-touched order is designed to ensure that profits are taken if sufficiently favorable price movements occur.

A *discretionary order* or *market-not-held order* is traded as a market order except that execution may be delayed at the broker's discretion in an attempt to get a better price.

Some orders specify time conditions. Unless otherwise stated, an order is a day order and expires at the end of the trading day. A *time-of-day order* specifies a particular period of time during the day when the order can be executed. An *open order* or a *good-till-canceled order* is in effect until executed or until the end of trading in the particular contract. A *fill-or-kill order,* as its name implies, must be executed immediately on receipt or not at all.

REGULATION

Futures markets in the United States are currently regulated federally by the Commodity Futures Trading Commission (CFTC; www.cftc.gov), which was established in 1974.

The CFTC looks after the public interest. It is responsible for ensuring that prices are communicated to the public and that futures traders report their outstanding positions if they are above certain levels. The CFTC also licenses all individuals who offer their services to the public in futures trading. The backgrounds of these individuals are investigated, and there are minimum capital requirements. The CFTC deals with complaints brought by the public and ensures that disciplinary action is taken against individuals when appropriate. It has the authority to force exchanges to take disciplinary action against members who are in violation of exchange rules.

With the formation of the National Futures Association (NFA; www.nfa.futures.org) in 1982, some of the responsibilities of the CFTC were shifted to the futures industry

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itself. The NFA is an organization of individuals who participate in the futures industry. Its objective is to prevent fraud and to ensure that the market operates in the best interests of the general public. It is authorized to monitor trading and take disciplinary action when appropriate. The agency has set up an efficient system for arbitrating disputes between individuals and its members.

The Dodd-Frank act, signed into law by President Obama in 2010, expanded the role of the CFTC. It is now responsible for rules requiring that standard over-the-counter derivatives be traded on swap execution facilities and cleared through central counterparties.

Trading Irregularities

Most of the time futures markets operate efficiently and in the public interest. However, from time to time, trading irregularities do come to light. One type of trading irregularity occurs when an investor group tries to "corner the market."[8] The investor group takes a huge long futures position and also tries to exercise some control over the supply of the underlying commodity. As the maturity of the futures contracts is approached, the investor group does not close out its position, so that the number of outstanding futures contracts may exceed the amount of the commodity available for delivery. The holders of short positions realize that they will find it difficult to deliver and become desperate to close out their positions. The result is a large rise in both futures and spot prices. Regulators usually deal with this type of abuse of the market by increasing margin requirements or imposing stricter position limits or prohibiting trades that increase a speculator's open position or requiring market participants to close out their positions.

Other types of trading irregularity can involve the traders on the floor of the exchange. These received some publicity early in 1989, when it was announced that the FBI had carried out a two-year investigation, using undercover agents, of trading on the Chicago Board of Trade and the Chicago Mercantile Exchange. The investigation was initiated because of complaints filed by a large agricultural concern. The alleged offenses included overcharging customers, not paying customers the full proceeds of sales, and traders using their knowledge of customer orders to trade first for themselves (an offence known as *front running*).

[8] Possibly the best known example of this was the attempt by the Hunt brothers to corner the silver market in 1979–80. Between the middle of 1979 and the beginning of 1980, their activities led to a price rise from $6 per ounce to $50 per ounce.

ACCOUNTING AND TAX

The full details of the accounting and tax treatment of futures contracts are beyond the scope of this book. A trader who wants detailed information on this should obtain professional advice. This section provides some general background information.

Accounting

Accounting standards require changes in the market value of a futures contract to be recognized when they occur unless the contract qualifies as a hedge. If the contract does qualify as a hedge, gains or losses are generally recognized for accounting purposes in the same period in which the gains or losses from the item being hedged are recognized. The latter treatment is referred to as *hedge accounting*.

Consider a company with a December year end. In September 2014 it buys a March 2015 corn futures contract and closes out the position at the end of February 2015. Suppose that the futures prices are 650 cents per bushel when the contract is entered into, 670 cents per bushel at the end of 2014, and 680 cents per bushel when the contract is closed out. The contract is for the delivery of 5,000 bushels. If the contract does not qualify as a hedge, the gains for accounting purposes are

$$5{,}000 \times (6.70 - 6.50) = \$1{,}000$$

in 2014 and

$$5{,}000 \times (6.80 - 6.70) = \$500$$

in 2015. If the company is hedging the purchase of 5,000 bushels of corn in February 2015 so that the contract qualifies for hedge accounting, the entire gain of $1,500 is realized in 2015 for accounting purposes.

The treatment of hedging gains and losses is sensible. If the company is hedging the purchase of 5,000 bushels of corn in February 2015, the effect of the futures contract is to ensure that the price paid is close to 650 cents per bushel. The accounting treatment reflects that this price is paid in 2015.

In June 1998, the Financial Accounting Standards Board issued Statement No. 133 (FAS 133), Accounting for Derivative Instruments and Hedging Activities. FAS 133

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applies to all types of derivatives (including futures, forwards, swaps, and options). It requires all derivatives to be included on the balance sheet at fair market value.[9] It increases disclosure requirements. It also gives companies far less latitude than previously in using hedge accounting. For hedge accounting to be used, the hedging instrument must be highly effective in offsetting exposures and an assessment of this effectiveness is required every three months. A similar standard, IAS 39, has been issued by the International Accounting Standards Board.

Tax

Under the US tax rules, two key issues are the nature of a taxable gain or loss and the timing of the recognition of the gain or loss. Gains or losses are either classified as capital gains or losses or alternatively as part of ordinary income.

For a corporate taxpayer, capital gains are taxed at the same rate as ordinary income, and the ability to deduct losses is restricted. Capital losses are deductible only to the extent of capital gains. A corporation may carry back a capital loss for three years and carry it forward for up to five years. For a noncorporate taxpayer, short-term capital gains are taxed at the same rate as ordinary income, but long-term capital gains are subject to a maximum capital gains tax rate of 15%. (Long-term capital gains are gains from the sale of a capital asset held for longer than one year; short-term capital gains are the gains from the sale of a capital asset held one year or less.) For a noncorporate taxpayer, capital losses are deductible to the extent of capital gains plus ordinary income up to $3,000 and can be carried forward indefinitely.

Generally, positions in futures contracts are treated as if they are closed out on the last day of the tax year. For the noncorporate taxpayer, this gives rise to capital gains and losses that are treated as if they were 60% long term and 40% short term without regard to the holding period. This is referred to as the "60/40" rule. A noncorporate taxpayer may elect to carry back for three years any net losses from the 60/40 rule to offset any gains recognized under the rule in the previous three years.

Hedging transactions are exempt from this rule. The definition of a hedge transaction for tax purposes is different from that for accounting purposes. The tax regulations define a hedging transaction as a transaction entered into in the normal course of business primarily for one of the following reasons:

1. To reduce the risk of price changes or currency fluctuations with respect to property that is held or to be held by the taxpayer for the purposes of producing ordinary income
2. To reduce the risk of price or interest rate changes or currency fluctuations with respect to borrowings made by the taxpayer.

A hedging transaction must be clearly identified in a timely manner in the company's records as a hedge. Gains or losses from hedging transactions are treated as ordinary income. The timing of the recognition of gains or losses from hedging transactions generally matches the timing of the recognition of income or expense associated with the transaction being hedged.

FORWARD VS. FUTURES CONTRACTS

The main differences between forward and futures contracts are summarized in Table 5-3. Both contracts are agreements to buy or sell an asset for a certain price at a certain future time. A forward contract is traded in the over-the-counter market and there is no standard contract size or standard delivery arrangements. A single delivery date is usually specified and the contract is usually held to the end of its life and then settled. A futures contract is a standardized contract traded on an exchange. A range

TABLE 5-3 Comparison of Forward and Futures Contracts

Forward	Futures
Private contract between two parties	Traded on an exchange
Not standardized	Standardized contract
Usually one specified delivery date	Range of delivery dates
Settled at end of contract	Settled daily
Delivery or final cash settlement usually takes place	Contract is usually closed out prior to maturity
Some credit risk	Virtually no credit risk

[9] Previously the attraction of derivatives in some situations was that they were "off-balance-sheet" items.

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of delivery dates is usually specified. It is settled daily and usually closed out prior to maturity.

Profits from Forward and Futures Contracts

Suppose that the sterling exchange rate for a 90-day forward contract is 1.5000 and that this rate is also the futures price for a contract that will be delivered in exactly 90 days. What is the difference between the gains and losses under the two contracts?

Under the forward contract, the whole gain or loss is realized at the end of the life of the contract. Under the futures contract, the gain or loss is realized day by day because of the daily settlement procedures. Suppose that trader A is long £1 million in a 90-day forward contract and trader B is long £1 million in 90-day futures contracts. (Because each futures contract is for the purchase or sale of £62,500, trader B must purchase a total of 16 contracts.) Assume that the spot exchange rate in 90 days proves to be 1.7000 dollars per pound. Trader A makes a gain of $200,000 on the 90th day. Trader B makes the same gain—but spread out over the 90-day period. On some days trader B may realize a loss, whereas on other days he or she makes a gain. However, in total, when losses are netted against gains, there is a gain of $200,000 over the 90-day period.

Foreign Exchange Quotes

Both forward and futures contracts trade actively on foreign currencies. However, there is sometimes a difference in the way exchange rates are quoted in the two markets. For example, futures prices where one currency is the US dollar are always quoted as the number of US dollars per unit of the foreign currency or as the number of US cents per unit of the foreign currency. Forward prices are always quoted in the same way as spot prices. This means that, for the British pound, the euro, the Australian dollar, and the New Zealand dollar, the forward quotes show the number of US dollars per unit of the foreign currency and are directly comparable with futures quotes. For other major currencies, forward quotes show the number of units of the foreign currency per US dollar (USD). Consider the Canadian dollar (CAD). A futures price quote of 0.9500 USD per CAD corresponds to a forward price quote of 1.0526 CAD per USD (1.0526 = 1/0.9500).

SUMMARY

A very high proportion of the futures contracts that are traded do not lead to the delivery of the underlying asset. Traders usually enter into offsetting contracts to close out their positions before the delivery period is reached. However, it is the possibility of final delivery that drives the determination of the futures price. For each futures contract, there is a range of days during which delivery can be made and a well-defined delivery procedure. Some contracts, such as those on stock indices, are settled in cash rather than by delivery of the underlying asset.

The specification of contracts is an important activity for a futures exchange. The two sides to any contract must know what can be delivered, where delivery can take place, and when delivery can take place. They also need to know details on the trading hours, how prices will be quoted, maximum daily price movements, and so on. New contracts must be approved by the Commodity Futures Trading Commission before trading starts.

Margin accounts are an important aspect of futures markets. An investor keeps a margin account with his or her broker. The account is adjusted daily to reflect gains or losses, and from time to time the broker may require the account to be topped up if adverse price movements have taken place. The broker either must be a clearing house member or must maintain a margin account with a clearing house member. Each clearing house member maintains a margin account with the exchange clearing house. The balance in the account is adjusted daily to reflect gains and losses on the business for which the clearing house member is responsible.

In over-the-counter derivatives markets, transactions are cleared either bilaterally or centrally. When bilateral clearing is used, collateral frequently has to be posted by one or both parties to reduce credit risk. When central clearing is used, a central counterparty (CCP) stands between the two sides. It requires each side to provide margin and performs much the same function as an exchange clearing house.

Forward contracts differ from futures contracts in a number of ways. Forward contracts are private arrangements between two parties, whereas futures contracts are traded on exchanges. There is generally a single delivery date in a forward contract, whereas futures contracts frequently

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involve a range of such dates. Because they are not traded on exchanges, forward contracts do not need to be standardized. A forward contract is not usually settled until the end of its life, and most contracts do in fact lead to delivery of the underlying asset or a cash settlement at this time.

In the next few chapters we shall examine in more detail the ways in which forward and futures contracts can be used for hedging. We shall also look at how forward and futures prices are determined.

Further Reading

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Hedging Strategies Using Futures

6

Learning Objectives

After completing this reading you should be able to:

- Define and differentiate between short and long hedges and identify their appropriate uses.
- Describe the arguments for and against hedging and the potential impact of hedging on firm profitability.
- Define the basis and explain the various sources of basis risk, and explain how basis risks arise when hedging with futures.
- Define cross hedging, and compute and interpret the minimum variance hedge ratio and hedge effectiveness.
- Compute the optimal number of futures contracts needed to hedge an exposure, and explain and calculate the "tailing the hedge" adjustment.
- Explain how to use stock index futures contracts to change a stock portfolio's beta.
- Explain the term "rolling the hedge forward" and describe some of the risks that arise from this strategy.

Excerpt is Chapter 3 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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Many of the participants in futures markets are hedgers. Their aim is to use futures markets to reduce a particular risk that they face. This risk might relate to fluctuations in the price of oil, a foreign exchange rate, the level of the stock market, or some other variable. A *perfect hedge* is one that completely eliminates the risk. Perfect hedges are rare. For the most part, therefore, a study of hedging using futures contracts is a study of the ways in which hedges can be constructed so that they perform as close to perfect as possible.

In this chapter we consider a number of general issues associated with the way hedges are set up. When is a short futures position appropriate? When is a long futures position appropriate? Which futures contract should be used? What is the optimal size of the futures position for reducing risk? At this stage, we restrict our attention to what might be termed *hedge-and-forget* strategies. We assume that no attempt is made to adjust the hedge once it has been put in place. The hedger simply takes a futures position at the beginning of the life of the hedge and closes out the position at the end of the life of the hedge.

The chapter initially treats futures contracts as forward contracts (that is, it ignores daily settlement). Later it explains an adjustment known as "tailing" that takes account of the difference between futures and forwards.

BASIC PRINCIPLES

When an individual or company chooses to use futures markets to hedge a risk, the objective is usually to take a position that neutralizes the risk as far as possible. Consider a company that knows it will gain $10,000 for each 1 cent increase in the price of a commodity over the next 3 months and lose $10,000 for each 1 cent decrease in the price during the same period. To hedge, the company's treasurer should take a short futures position that is designed to offset this risk. The futures position should lead to a loss of $10,000 for each 1 cent increase in the price of the commodity over the 3 months and a gain of $10,000 for each 1 cent decrease in the price during this period. If the price of the commodity goes down, the gain on the futures position offsets the loss on the rest of the company's business. If the price of the commodity goes up, the loss on the futures position is offset by the gain on the rest of the company's business.

Short Hedges

A *short hedge* is a hedge, such as the one just described, that involves a short position in futures contracts. A short hedge is appropriate when the hedger already owns an asset and expects to sell it at some time in the future. For example, a short hedge could be used by a farmer who owns some hogs and knows that they will be ready for sale at the local market in two months. A short hedge can also be used when an asset is not owned right now but will be owned at some time in the future. Consider, for example, a US exporter who knows that he or she will receive euros in 3 months. The exporter will realize a gain if the euro increases in value relative to the US dollar and will sustain a loss if the euro decreases in value relative to the US dollar. A short futures position leads to a loss if the euro increases in value and a gain if it decreases in value. It has the effect of offsetting the exporter's risk.

To provide a more detailed illustration of the operation of a short hedge in a specific situation, we assume that it is May 15 today and that an oil producer has just negotiated a contract to sell 1 million barrels of crude oil. It has been agreed that the price that will apply in the contract is the market price on August 15. The oil producer is therefore in the position where it will gain $10,000 for each 1 cent increase in the price of oil over the next 3 months and lose $10,000 for each 1 cent decrease in the price during this period. Suppose that on May 15 the spot price is $80 per barrel and the crude oil futures price for August delivery is $79 per barrel. Because each futures contract is for the delivery of 1,000 barrels, the company can hedge its exposure by shorting (i.e., selling) 1,000 futures contracts. If the oil producer closes out its position on August 15, the effect of the strategy should be to lock in a price close to $79 per barrel.

To illustrate what might happen, suppose that the spot price on August 15 proves to be $75 per barrel. The company realizes $75 million for the oil under its sales contract. Because August is the delivery month for the futures contract, the futures price on August 15 should be very close to the spot price of $75 on that date. The company therefore gains approximately

$$\$79 - \$75 = \$4$$

per barrel, or $4 million in total from the short futures position. The total amount realized from both the futures position and the sales contract is therefore approximately $79 per barrel, or $79 million in total.

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For an alternative outcome, suppose that the price of oil on August 15 proves to be $85 per barrel. The company realizes $85 per barrel for the oil and loses approximately

$$\$85 - \$79 = \$6$$

per barrel on the short futures position. Again, the total amount realized is approximately $79 million. It is easy to see that in all cases the company ends up with approximately $79 million.

Long Hedges

Hedges that involve taking a long position in a futures contract are known as *long hedges*. A long hedge is appropriate when a company knows it will have to purchase a certain asset in the future and wants to lock in a price now.

Suppose that it is now January 15. A copper fabricator knows it will require 100,000 pounds of copper on May 15 to meet a certain contract. The spot price of copper is 340 cents per pound, and the futures price for May delivery is 320 cents per pound. The fabricator can hedge its position by taking a long position in four futures contracts offered by the COMEX division of the CME Group and closing its position on May 15. Each contract is for the delivery of 25,000 pounds of copper. The strategy has the effect of locking in the price of the required copper at close to 320 cents per pound.

Suppose that the spot price of copper on May 15 proves to be 325 cents per pound. Because May is the delivery month for the futures contract, this should be very close to the futures price. The fabricator therefore gains approximately

$$100{,}000 \times (\$3.25 - \$3.20) = \$5{,}000$$

on the futures contracts. It pays 100,000 × $3.25 = $325,000 for the copper, making the net cost approximately $325,000 − $5,000 = $320,000. For an alternative outcome, suppose that the spot price is 305 cents per pound on May 15. The fabricator then loses approximately

$$100{,}000 \times (\$3.20 - \$3.05) = \$15{,}000$$

on the futures contract and pays 100,000 × $3.05 = $305,000 for the copper. Again, the net cost is approximately $320,000, or 320 cents per pound.

Note that, in this case, it is clearly better for the company to use futures contracts than to buy the copper on January 15 in the spot market. If it does the latter, it will pay 340 cents per pound instead of 320 cents per pound and will incur both interest costs and storage costs. For a company using copper on a regular basis, this disadvantage would be offset by the convenience of having the copper on hand.[1] However, for a company that knows it will not require the copper until May 15, the futures contract alternative is likely to be preferred.

The examples we have looked at assume that the futures position is closed out in the delivery month. The hedge has the same basic effect if delivery is allowed to happen. However, making or taking delivery can be costly and inconvenient. For this reason, delivery is not usually made even when the hedger keeps the futures contract until the delivery month. As will be discussed later, hedgers with long positions usually avoid any possibility of having to take delivery by closing out their positions before the delivery period.

We have also assumed in the two examples that there is no daily settlement. In practice, daily settlement does have a small effect on the performance of a hedge. As explained in Chapter 5, it means that the payoff from the futures contract is realized day by day throughout the life of the hedge rather than all at the end.

ARGUMENTS FOR AND AGAINST HEDGING

The arguments in favor of hedging are so obvious that they hardly need to be stated. Most nonfinancial companies are in the business of manufacturing, or retailing or wholesaling, or providing a service. They have no particular skills or expertise in predicting variables such as interest rates, exchange rates, and commodity prices. It makes sense for them to hedge the risks associated with these variables as they become aware of them. The companies can then focus on their main activities—for which presumably they do have particular skills and expertise. By hedging, they avoid unpleasant surprises such as sharp rises in the price of a commodity that is being purchased.

In practice, many risks are left unhedged. In the rest of this section we will explore some of the reasons for this.

Hedging and Shareholders

One argument sometimes put forward is that the shareholders can, if they wish, do the hedging themselves.

[1] See Chapter 8 for a discussion of convenience yields.

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They do not need the company to do it for them. This argument is, however, open to question. It assumes that shareholders have as much information as the company's management about the risks faced by a company. In most instances, this is not the case. The argument also ignores commissions and other transactions costs. These are less expensive per dollar of hedging for large transactions than for small transactions. Hedging is therefore likely to be less expensive when carried out by the company than when it is carried out by individual shareholders. Indeed, the size of futures contracts makes hedging by individual shareholders impossible in many situations.

One thing that shareholders can do far more easily than a corporation is diversify risk. A shareholder with a well-diversified portfolio may be immune to many of the risks faced by a corporation. For example, in addition to holding shares in a company that uses copper, a well-diversified shareholder may hold shares in a copper producer, so that there is very little overall exposure to the price of copper. If companies are acting in the best interests of well-diversified shareholders, it can be argued that hedging is unnecessary in many situations. However, the extent to which managers are in practice influenced by this type of argument is open to question.

Hedging and Competitors

If hedging is not the norm in a certain industry, it may not make sense for one particular company to choose to be different from all others. Competitive pressures within the industry may be such that the prices of the goods and services produced by the industry fluctuate to reflect raw material costs, interest rates, exchange rates, and so on. A company that does not hedge can expect its profit margins to be roughly constant. However, a company that does hedge can expect its profit margins to fluctuate!

To illustrate this point, consider two manufacturers of gold jewelry, SafeandSure Company and TakeaChance Company. We assume that most companies in the industry do not hedge against movements in the price of gold and that TakeaChance Company is no exception. However, SafeandSure Company has decided to be different from its competitors and to use futures contracts to hedge its purchase of gold over the next 18 months. If the price of gold goes up, economic pressures will tend to lead to a corresponding increase in the wholesale price of jewelry, so that TakeaChance Company's gross profit margin is unaffected. By contrast, SafeandSure Company's profit margin will increase after the effects of the hedge have been taken into account. If the price of gold goes down, economic pressures will tend to lead to a corresponding decrease in the wholesale price of jewelry. Again, TakeaChance Company's profit margin is unaffected. However, SafeandSure Company's profit margin goes down. In extreme conditions, SafeandSure Company's profit margin could become negative as a result of the "hedging" carried out! The situation is summarized in Table 6-1.

TABLE 6-1 Danger in Hedging When Competitors Do Not Hedge

Change in Gold Price	Effect on Price of Gold Jewelry	Effect on Profits of TakeaChance Co.	Effect on Profits of SafeandSure Co.
Increase	Increase	None	Increase
Decrease	Decrease	None	Decrease

This example emphasizes the importance of looking at the big picture when hedging. All the implications of price changes on a company's profitability should be taken into account in the design of a hedging strategy to protect against the price changes.

Hedging Can Lead to a Worse Outcome

It is important to realize that a hedge using futures contracts can result in a decrease or an increase in a company's profits relative to the position it would be in with no hedging. In the example involving the oil producer considered earlier, if the price of oil goes down, the company loses money on its sale of 1 million barrels of oil, and the futures position leads to an offsetting gain. The treasurer can be congratulated for having had the foresight to put the hedge in place. Clearly, the company is better off than it would be with no hedging. Other executives in the organization, it is hoped, will appreciate the contribution made by the treasurer. If the price of oil goes up, the company gains from its sale of the oil, and the futures position leads to an offsetting loss. The company is in a worse position than it would be with no hedging. Although the hedging decision was perfectly logical, the treasurer may in practice have a difficult time justifying it. Suppose that the price of oil at the end of the hedge is $89, so that the

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company loses $10 per barrel on the futures contract. We can imagine a conversation such as the following between the treasurer and the president:

> President: This is terrible. We've lost $10 million in the futures market in the space of three months. How could it happen? I want a full explanation.
>
> Treasurer: The purpose of the futures contracts was to hedge our exposure to the price of oil, not to make a profit. Don't forget we made $10 million from the favorable effect of the oil price increases on our business.
>
> President: What's that got to do with it? That's like saying that we do not need to worry when our sales are down in California because they are up in New York.
>
> Treasurer: If the price of oil had gone down . . .
>
> President: I don't care what would have happened if the price of oil had gone down. The fact is that it went up. I really do not know what you were doing playing the futures markets like this. Our shareholders will expect us to have done particularly well this quarter. I'm going to have to explain to them that your actions reduced profits by $10 million. I'm afraid this is going to mean no bonus for you this year.
>
> Treasurer: That's unfair. I was only . . .
>
> President: Unfair! You are lucky not to be fired. You lost $10 million.
>
> Treasurer: It all depends on how you look at it . . .

It is easy to see why many treasurers are reluctant to hedge! Hedging reduces risk for the company. However, it may increase risk for the treasurer if others do not fully understand what is being done. The only real solution to this problem involves ensuring that all senior executives within the organization fully understand the nature of hedging before a hedging program is put in place. Ideally, hedging strategies are set by a company's board of directors and are clearly communicated to both the company's management and the shareholders. (See Box 6-1 for a discussion of hedging by gold mining companies.)

BOX 6-1 Hedging by Gold Mining Companies

It is natural for a gold mining company to consider hedging against changes in the price of gold. Typically it takes several years to extract all the gold from a mine. Once a gold mining company decides to go ahead with production at a particular mine, it has a big exposure to the price of gold. Indeed a mine that looks profitable at the outset could become unprofitable if the price of gold plunges.

Gold mining companies are careful to explain their hedging strategies to potential shareholders. Some gold mining companies do not hedge. They tend to attract shareholders who buy gold stocks because they want to benefit when the price of gold increases and are prepared to accept the risk of a loss from a decrease in the price of gold. Other companies choose to hedge. They estimate the number of ounces of gold they will produce each month for the next few years and enter into short futures or forward contracts to lock in the price for all or part of this.

Suppose you are Goldman Sachs and are approached by a gold mining company that wants to sell you a large amount of gold in 1 year at a fixed price. How do you set the price and then hedge your risk? The answer is that you can hedge by borrowing the gold from a central bank, selling it immediately in the spot market, and investing the proceeds at the risk-free rate. At the end of the year, you buy the gold from the gold mining company and use it to repay the central bank. The fixed forward price you set for the gold reflects the risk-free rate you can earn and the lease rate you pay the central bank for borrowing the gold.

BASIS RISK

The hedges in the examples considered so far have been almost too good to be true. The hedger was able to identify the precise date in the future when an asset would be bought or sold. The hedger was then able to use futures contracts to remove almost all the risk arising from the price of the asset on that date. In practice, hedging is often not quite as straightforward as this. Some of the reasons are as follows:

1. The asset whose price is to be hedged may not be exactly the same as the asset underlying the futures contract.
2. The hedger may be uncertain as to the exact date when the asset will be bought or sold.
3. The hedge may require the futures contract to be closed out before its delivery month.

These problems give rise to what is termed *basis risk*. This concept will now be explained.

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The Basis

The *basis* in a hedging situation is as follows:[2]

Basis = Spot price of asset to be hedged
− Futures price of contract used

If the asset to be hedged and the asset underlying the futures contract are the same, the basis should be zero at the expiration of the futures contract. Prior to expiration, the basis may be positive or negative. From Table 5-2, we see that, on May 14, 2013, the basis was negative for gold and positive for short maturity contracts on corn and soybeans.

As time passes, the spot price and the futures price for a particular month do not necessarily change by the same amount. As a result, the basis changes. An increase in the basis is referred to as a *strengthening of the basis*; a decrease in the basis is referred to as a *weakening of the basis*. Figure 6-1 illustrates how a basis might change over time in a situation where the basis is positive prior to expiration of the futures contract.

To examine the nature of basis risk, we will use the following notation:

- S_1: Spot price at time t_1
- S_2: Spot price at time t_2
- F_1: Futures price at time t_1
- F_2: Futures price at time t_2
- b_1: Basis at time t_1
- b_2: Basis at time t_2.

We will assume that a hedge is put in place at time t_1 and closed out at time t_2. As an example, we will consider the case where the spot and futures prices at the time the hedge is initiated are \$2.50 and \$2.20, respectively, and that at the time the hedge is closed out they are \$2.00 and \$1.90, respectively. This means that $S_1 = 2.50$, $F_1 = 2.20$, $S_2 = 2.00$, and $F_2 = 1.90$.

From the definition of the basis, we have

$$b_1 = S_1 - F_1 \quad \text{and} \quad b_2 = S_2 - F_2$$

so that, in our example, $b_1 = 0.30$ and $b_2 = 0.10$.

[2] This is the usual definition. However, the alternative definition Basis = Futures price − Spot price is sometimes used, particularly when the futures contract is on a financial asset.

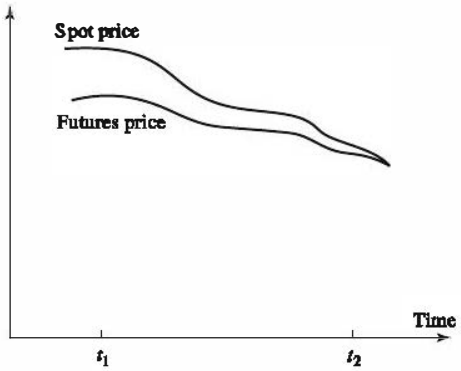

FIGURE 6-1 Variation of basis over time.

Consider first the situation of a hedger who knows that the asset will be sold at time t_2 and takes a short futures position at time t_1. The price realized for the asset is S_2 and the profit on the futures position is $F_1 - F_2$. The effective price that is obtained for the asset with hedging is therefore

$$S_2 + F_1 - F_2 = F_1 + b_2$$

In our example, this is \$2.30. The value of F_1 is known at time t_1. If b_2 were also known at this time, a perfect hedge would result. The hedging risk is the uncertainty associated with b_2 and is known as *basis risk*. Consider next a situation where a company knows it will buy the asset at time t_2 and initiates a long hedge at time t_1. The price paid for the asset is S_2 and the loss on the hedge is $F_1 - F_2$. The effective price that is paid with hedging is therefore

$$S_2 + F_1 - F_2 = F_1 + b_2$$

This is the same expression as before and is \$2.30 in the example. The value of F_1 is known at time t_1, and the term b_2 represents basis risk.

Note that basis changes can lead to an improvement or a worsening of a hedger's position. Consider a company that uses a short hedge because it plans to sell the underlying asset. If the basis strengthens (i.e., increases) unexpectedly, the company's position improves because it will get a higher price for the asset after futures gains or losses are considered; if the basis weakens (i.e., decreases) unexpectedly, the company's position worsens. For a company using a long hedge because it plans to

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buy the asset, the reverse holds. If the basis strengthens unexpectedly, the company's position worsens because it will pay a higher price for the asset after futures gains or losses are considered; if the basis weakens unexpectedly, the company's position improves.

The asset that gives rise to the hedger's exposure is sometimes different from the asset underlying the futures contract that is used for hedging. This is known as *cross hedging* and is discussed in the next section. It leads to an increase in basis risk. Define S_2^* as the price of the asset underlying the futures contract at time t_2. As before, S_2 is the price of the asset being hedged at time t_2. By hedging, a company ensures that the price that will be paid (or received) for the asset is

$$S_2 + F_1 - F_2$$

This can be written as

$$F_1 + (S_2^* - F_2) + (S_2 - S_2^*)$$

The terms $S_2^* - F_2$ and $S_2 - S_2^*$ represent the two components of the basis. The $S_2^* - F_2$ term is the basis that would exist if the asset being hedged were the same as the asset underlying the futures contract. The $S_2 - S_2^*$ term is the basis arising from the difference between the two assets.

Choice of Contract

One key factor affecting basis risk is the choice of the futures contract to be used for hedging. This choice has two components:

1. The choice of the asset underlying the futures contract
2. The choice of the delivery month.

If the asset being hedged exactly matches an asset underlying a futures contract, the first choice is generally fairly easy. In other circumstances, it is necessary to carry out a careful analysis to determine which of the available futures contracts has futures prices that are most closely correlated with the price of the asset being hedged.

The choice of the delivery month is likely to be influenced by several factors. In the examples given earlier in this chapter, we assumed that, when the expiration of the hedge corresponds to a delivery month, the contract with that delivery month is chosen. In fact, a contract with a later delivery month is usually chosen in these circumstances. The reason is that futures prices are in some instances quite erratic during the delivery month. Moreover, a long hedger runs the risk of having to take delivery of the physical asset if the contract is held during the delivery month. Taking delivery can be expensive and inconvenient. (Long hedgers normally prefer to close out the futures contract and buy the asset from their usual suppliers.)

In general, basis risk increases as the time difference between the hedge expiration and the delivery month increases. A good rule of thumb is therefore to choose a delivery month that is as close as possible to, but later than, the expiration of the hedge. Suppose delivery months are March, June, September, and December for a futures contract on a particular asset. For hedge expirations in December, January, and February, the March contract will be chosen; for hedge expirations in March, April, and May, the June contract will be chosen; and so on. This rule of thumb assumes that there is sufficient liquidity in all contracts to meet the hedger's requirements. In practice, liquidity tends to be greatest in short-maturity futures contracts. Therefore, in some situations, the hedger may be inclined to use short-maturity contracts and roll them forward. This strategy is discussed later in the chapter.

Example 6.1

It is March 1. A US company expects to receive 50 million Japanese yen at the end of July. Yen futures contracts on the CME Group have delivery months of March, June, September, and December. One contract is for the delivery of 12.5 million yen. The company therefore shorts four September yen futures contracts on March 1. When the yen are received at the end of July, the company closes out its position. We suppose that the futures price on March 1 in cents per yen is 0.9800 and that the spot and futures prices when the contract is closed out are 0.9200 and 0.9250, respectively.

The gain on the futures contract is 0.9800 − 0.9250 = 0.0550 cents per yen. The basis is 0.9200 − 0.9250 = 0.0050 cents per yen when the contract is closed out. The effective price obtained in cents per yen is the final spot price plus the gain on the futures:

$$0.9200 + 0.0550 = 0.9750$$

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This can also be written as the initial futures price plus the final basis:

$$0.9800 + (-0.0050) = 0.9750$$

The total amount received by the company for the 50 million yen is 50 × 0.00975 million dollars, or $487,500.

Example 6.2

It is June 8 and a company knows that it will need to purchase 20,000 barrels of crude oil at some time in October or November. Oil futures contracts are currently traded for delivery every month on the NYMEX division of the CME Group and the contract size is 1,000 barrels. The company therefore decides to use the December contract for hedging and takes a long position in 20 December contracts. The futures price on June 8 is $88.00 per barrel. The company finds that it is ready to purchase the crude oil on November 10. It therefore closes out its futures contract on that date. The spot price and futures price on November 10 are $90.00 per barrel and $89.10 per barrel.

The gain on the futures contract is 89.10 − 88.00 = $1.10 per barrel. The basis when the contract is closed out is 90.00 − 89.10 = $0.90 per barrel. The effective price paid (in dollars per barrel) is the final spot price less the gain on the futures, or

$$90.00 - 1.10 = 88.90$$

This can also be calculated as the initial futures price plus the final basis,

$$88.00 + 0.90 = 88.90$$

The total price paid is 88.90 × 20,000 = $1,778,000.

CROSS HEDGING

In Examples 6.1 and 6.2, the asset underlying the futures contract was the same as the asset whose price is being hedged. *Cross hedging* occurs when the two assets are different. Consider, for example, an airline that is concerned about the future price of jet fuel. Because jet fuel futures are not actively traded, it might choose to use heating oil futures contracts to hedge its exposure.

The *hedge ratio* is the ratio of the size of the position taken in futures contracts to the size of the exposure. When the asset underlying the futures contract is the same as the asset being hedged, it is natural to use a hedge ratio of 1.0. This is the hedge ratio we have used in the examples considered so far. For instance, in Example 6.2, the hedger's exposure was on 20,000 barrels of oil, and futures contracts were entered into for the delivery of exactly this amount of oil.

When cross hedging is used, setting the hedge ratio equal to 1.0 is not always optimal. The hedger should choose a value for the hedge ratio that minimizes the variance of the value of the hedged position. We now consider how the hedger can do this.

Calculating the Minimum Variance Hedge Ratio

The minimum variance hedge ratio depends on the relationship between changes in the spot price and changes in the futures price. Define:

ΔS: Change in spot price, S, during a period of time equal to the life of the hedge

ΔF: Change in futures price, F, during a period of time equal to the life of the hedge.

We will denote the minimum variance hedge ratio by h^*. It can be shown that h^* is the slope of the best-fit line from a linear regression of ΔS against ΔF (see Figure 6-2).

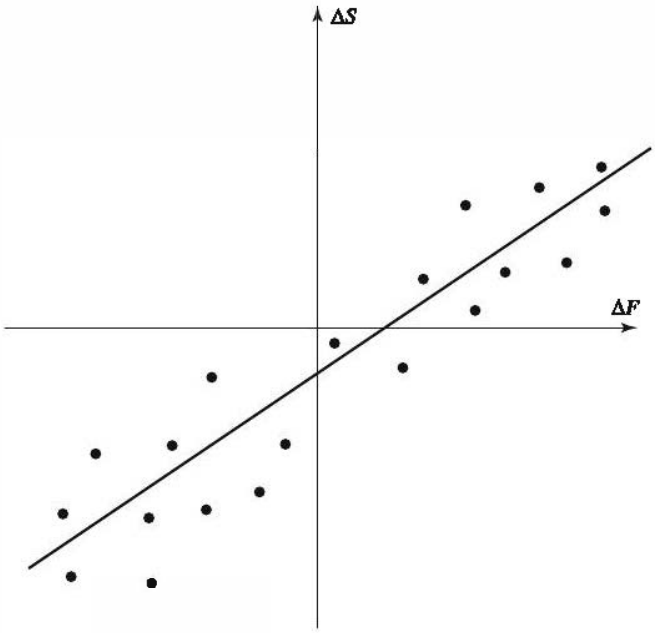

FIGURE 6-2 Regression of change in spot price against change in futures price.

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This result is intuitively reasonable. We would expect h^* to be the ratio of the average change in S for a particular change in F.

The formula for h^* is:

$$h^* = \rho\frac{\sigma_S}{\sigma_F} \tag{6.1}$$

where σ_S is the standard deviation of ΔS, σ_F is the standard deviation of ΔF, and ρ is the coefficient of correlation between the two.

Equation (6.1) shows that the optimal hedge ratio is the product of the coefficient of correlation between ΔS and ΔF and the ratio of the standard deviation of ΔS to the standard deviation of ΔF. Figure 6-3 shows how the variance of the value of the hedger's position depends on the hedge ratio chosen.

If $\rho = 1$ and $\sigma_F = \sigma_S$, hedge ratio, h^*, is 1.0. This result is to be expected, because in this case the futures price mirrors the spot price perfectly. If $\rho = 1$ and $\sigma_F = 2\sigma_S$, the hedge ratio h^* is 0.5. This result is also as expected, because in this case the futures price always changes by twice as much as the spot price. The *hedge effectiveness* can be defined as the proportion of the variance that is eliminated by hedging. This is the R^2 from the regression of ΔS against ΔF and equals ρ^2.

The parameters ρ, σ_F, and σ_S in Equation (6.1) are usually estimated from historical data on ΔS and ΔF. (The implicit assumption is that the future will in some sense be like the past.) A number of equal nonoverlapping time intervals are chosen, and the values of ΔS and ΔF for each of the intervals are observed. Ideally, the length of each time interval is the same as the length of the time interval for which the hedge is in effect. In practice, this sometimes severely limits the number of observations that are available, and a shorter time interval is used.

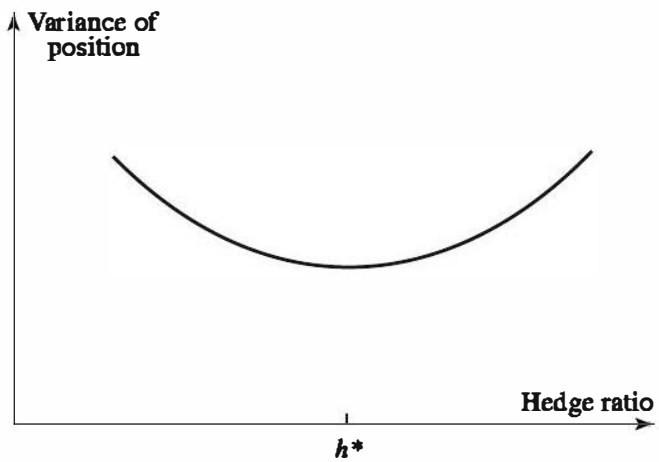

FIGURE 6-3 Dependence of variance of hedger's position on hedge ratio.

Optimal Number of Contracts

To calculate the number of contracts that should be used in hedging, define:

Q_A: Size of position being hedged (units)

Q_F: Size of one futures contract (units)

N^*: Optimal number of futures contracts for hedging.

The futures contracts should be on h^*Q_A units of the asset. The number of futures contracts required is therefore given by

$$N^* = \frac{h^*Q_A}{Q_F} \tag{8.2}$$

Example 6.3 shows how the results in this section can be used by an airline hedging the purchase of jet fuel.[3]

Example 6.3

An airline expects to purchase 2 million gallons of jet fuel in 1 month and decides to use heating oil futures for hedging. We suppose that Table 6-2 gives, for 15 successive months, data on the change, ΔS, in the jet fuel price per gallon and the corresponding change, ΔF, in the futures price for the contract on heating oil that would be used for hedging price changes during the month. In this case, the usual formulas for calculating standard deviations and correlations give $\sigma_F = 0.0313$, $\sigma_S = 0.0263$, and $\rho = 0.928$.

From Equation (6.1), the minimum variance hedge ratio, h^*, is therefore

$$0.928 \times \frac{0.0263}{0.0313} = 0.78$$

[3] Derivatives with payoffs dependent on the price of jet fuel do exist, but heating oil futures are often used to hedge an exposure to jet fuel prices because they are traded more actively.

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TABLE 6-2 Data to Calculate Minimum Variance Hedge Ratio When Heating Oil Futures Contract Is Used to Hedge Purchase of Jet Fuel

Month i	Change in Heating Oil Futures Price per Gallon ($= \Delta F$)	Change in Jet Fuel Price per Gallon ($= \Delta S$)
1	0.021	0.029
2	0.035	0.020
3	−0.046	−0.044
4	0.001	0.008
5	0.044	0.026
6	−0.029	−0.019
7	−0.026	−0.010
8	−0.029	−0.007
9	0.048	0.043
10	−0.006	0.011
11	−0.036	−0.036
12	−0.011	−0.018
13	0.019	0.009
14	−0.027	−0.032
15	0.029	0.023

Each heating oil contract traded by the CME Group is on 42,000 gallons of heating oil. From Equation (6.2), the optimal number of contracts is

$$\frac{0.78 \times 2{,}000{,}000}{42{,}000}$$

which is 37 when rounded to the nearest whole number.

Tailing the Hedge

The analysis we have given so far is correct if we are using forward contracts to hedge. This is because in that case we are interested in how closely correlated the change in the forward price is with the change in the spot price over the life of the hedge.

When futures contracts are used for hedging, there is daily settlement and series of one-day hedges. To reflect this, analysts sometimes calculate the correlation between percentage one-day changes in the futures and spot prices. We will denote this correlation by $\hat{\rho}$, and define $\hat{\sigma}_S$ and $\hat{\sigma}_F$ as the standard deviations of percentage one-day changes in spot and futures prices.

If S and F are the current spot and futures prices, the standard deviations of one-day price changes are $S\hat{\sigma}_S$ and $F\hat{\sigma}_F$ and from Equation (6.1) the one-day hedge ratio is

$$\hat{\rho}\frac{S\hat{\sigma}_S}{F\hat{\sigma}_F}$$

From Equation (6.2), the number of contracts needed to hedge over the next day is

$$N^* = \hat{\rho}\frac{S\hat{\sigma}_S Q_A}{F\hat{\sigma}_F Q_F}$$

Using this result is sometimes referred to as *tailing the hedge*. We can write the result as

$$N^* = \hat{h}\frac{V_A}{V_F} \tag{8.3}$$

where V_A is the dollar value of the position being hedged ($= SQ_A$), V_F is the dollar value of one futures contract ($= FQ_F$) and $\hat{h}$ is defined similarly to h^* as

$$\hat{h} = \hat{\rho}\frac{\hat{\sigma}_S}{\hat{\sigma}_F}$$

In theory this result suggests that we should change the futures position every day to reflect the latest values of V_A and V_F. In practice, day-to-day changes in the hedge are very small and usually ignored.

STOCK INDEX FUTURES

We now move on to consider stock index futures and how they are used to hedge or manage exposures to equity prices.

A *stock index* tracks changes in the value of a hypothetical portfolio of stocks. The weight of a stock in the portfolio at a particular time equals the proportion of the hypothetical portfolio invested in the stock at that time. The percentage increase in the stock index over a small interval of time is set equal to the percentage increase in the value of the hypothetical portfolio. Dividends

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are usually not included in the calculation so that the index tracks the capital gain/loss from investing in the portfolio.[4]

If the hypothetical portfolio of stocks remains fixed, the weights assigned to individual stocks in the portfolio do not remain fixed. When the price of one particular stock in the portfolio rises more sharply than others, more weight is automatically given to that stock. Sometimes indices are constructed from a hypothetical portfolio consisting of one of each of a number of stocks. The weights assigned to the stocks are then proportional to their market prices, with adjustments being made when there are stock splits. Other indices are constructed so that weights are proportional to market capitalization (stock price × number of shares outstanding). The underlying portfolio is then automatically adjusted to reflect stock splits, stock dividends, and new equity issues.

Stock Indices

Table 6-3 shows futures prices for contracts on three different stock indices on May 14, 2013.

[4] An exception to this is a *total return index*. This is calculated by assuming that dividends on the hypothetical portfolio are reinvested in the portfolio.

The *Dow Jones Industrial Average* is based on a portfolio consisting of 30 blue-chip stocks in the United States. The weights given to the stocks are proportional to their prices. The CME Group trades two futures contracts on the index. One is on $10 times the index. The other (the Mini DJ Industrial Average) is on $5 times the index. The Mini contract trades most actively.

The *Standard & Poor's 500* (S&P 500) *Index* is based on a portfolio of 500 different stocks: 400 industrials, 40 utilities, 20 transportation companies, and 40 financial institutions. The weights of the stocks in the portfolio at any given time are proportional to their market capitalizations. The stocks are those of large publicly held companies that trade on NYSE Euronext or Nasdaq OMX. The CME Group trades two futures contracts on the S&P 500. One is on $250 times the index; the other (the Mini S&P 500 contract) is on $50 times the index. The Mini contract trades most actively.

The *Nasdaq-100* is based on 100 stocks using the National Association of Securities Dealers Automatic Quotations Service. The CME Group trades two futures contracts. One is on $100 times the index; the other (the Mini Nasdaq-100 contract) is on $20 times the index. The Mini contract trades most actively.

As mentioned in Chapter 5, futures contracts on stock indices are settled in cash, not by delivery of the

TABLE 6-3 Index Futures Quotes as Reported by the CME Group on May 14, 2013

	Open	High	Low	Prior Settlement	Last Trade	Change	Volume
Mini Dow Jones Industrial Average, $5 times Index							
June 2013	15055	15159	15013	15057	15152	+95	88,510
Sept. 2013	14982	15089	14947	14989	15081	+92	34
Mini S&P 500, $50 times Index							
June 2013	1630.75	1647.50	1626.50	1630.75	1646.00	+15.25	1,397,446
Sept. 2013	1625.00	1641.50	1620.50	1625.00	1640.00	+15.00	4,360
Dec. 2013	1619.75	1635.00	1615.75	1618.50	1633.75	+15.25	143
Mini NASDAQ-100, $20 times Index							
June 2013	2981.25	3005.00	2971.25	2981.00	2998.00	+17.00	126,821
Sept. 2013	2979.50	2998.00	2968.00	2975.50	2993.00	+17.50	337

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underlying asset. All contracts are marked to market to either the opening price or the closing price of the index on the last trading day, and the positions are then deemed to be closed. For example, contracts on the S&P 500 are closed out at the opening price of the S&P 500 index on the third Friday of the delivery month.

Hedging an Equity Portfolio

Stock index futures can be used to hedge a well-diversified equity portfolio. Define:

V_A: Current value of the portfolio

V_F: Current value of one futures contract (the futures price times the contract size).

If the portfolio mirrors the index, the optimal hedge ratio can be assumed to be 1.0 and Equation (6.3) shows that the number of futures contracts that should be shorted is

$$N^* = \frac{V_A}{V_F} \tag{8.4}$$

Suppose, for example, that a portfolio worth $5,050,000 mirrors the S&P 500. The index futures price is 1,010 and each futures contract is on $250 times the index. In this case V_A = 5,050,000 and V_F = 1,010 × 250 = 252,500, so that 20 contracts should be shorted to hedge the portfolio.

When the portfolio does not mirror the index, we can use the capital asset pricing model (see the appendix to this chapter). The parameter beta (β) from the capital asset pricing model is the slope of the best-fit line obtained when excess return on the portfolio over the risk-free rate is regressed against the excess return of the index over the risk-free rate. When β = 1.0, the return on the portfolio tends to mirror the return on the index; when β = 2.0, the excess return on the portfolio tends to be twice as great as the excess return on the index; when β = 0.5, it tends to be half as great; and so on.

A portfolio with a β of 2.0 is twice as sensitive to movements in the index as a portfolio with a beta 1.0. It is therefore necessary to use twice as many contracts to hedge the portfolio. Similarly, a portfolio with a beta of 0.5 is half as sensitive to market movements as a portfolio with a beta of 1.0 and we should use half as many contracts to hedge it. In general,

$$N^* = \beta\frac{V_A}{V_F} \tag{8.5}$$

This formula assumes that the maturity of the futures contract is close to the maturity of the hedge.

Comparing Equation (6.5) with Equation (6.3), we see that they imply $\hat{h} = \beta$. This is not surprising. The hedge ratio $\hat{h}$ is the slope of the best-fit line when percentage one-day changes in the portfolio are regressed against percentage one-day changes in the futures price of the index. Beta (β) is the slope of the best-fit line when the return from the portfolio is regressed against the return for the index.

We illustrate that this formula gives good results by extending our earlier example. Suppose that a futures contract with 4 months to maturity is used to hedge the value of a portfolio over the next 3 months in the following situation:

Value of S&P 500 index = 1,000
S&P 500 futures price = 1,010
Value of portfolio = $5,050,000
Risk-free interest rate = 4% per annum
Dividend yield on index = 1% per annum
Beta of portfolio = 1.5

One futures contract is for delivery of $250 times the index. As before, V_F = 250 × 1,010 = 252,500. From Equation (6.5), the number of futures contracts that should be shorted to hedge the portfolio is

$$1.5 \times \frac{5{,}050{,}000}{252{,}500} = 30$$

Suppose the index turns out to be 900 in 3 months and the futures price is 902. The gain from the short futures position is then

$$30 \times (1010 - 902) \times 250 = \$810{,}000$$

The loss on the index is 10%. The index pays a dividend of 1% per annum, or 0.25% per 3 months. When dividends are taken into account, an investor in the index would therefore earn −9.75% over the 3-month period. Because the portfolio has a β of 1.5, the capital asset pricing model gives

Expected return on portfolio − Risk-free interest rate
= 1.5 × (Return on index − Risk-free interest rate)

The risk-free interest rate is approximately 1% per 3 months. It follows that the expected return (%) on the portfolio during the 3 months when the 3-month return on the index is −9.75% is

$$1.0 + [1.5 \times (-9.75 - 1.0)] = -15.125$$

The expected value of the portfolio (inclusive of dividends) at the end of the 3 months is therefore

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TABLE 6-4 Performance of Stock Index Hedge

Value of index in three months:	900	950	1,000	1,050	1,100
Futures price of index today:	1,010	1,010	1,010	1,010	1,010
Futures price of index in three months:	902	952	1,003	1,053	1,103
Gain on futures position ($):	810,000	435,000	52,500	−322,500	−697,500
Return on market:	−9.750%	−4.750%	0.250%	5.250%	10.250%
Expected return on portfolio:	−15.125%	−7.625%	−0.125%	7.375%	14.875%
Expected portfolio value in three months including dividends ($):	4,286,187	4,664,937	5,043,687	5,422,437	5,801,187
Total value of position in three months ($):	5,096,187	5,099,937	5,096,187	5,099,937	5,103,687

$$\$5{,}050{,}000 \times (1 - 0.15125) = \$4{,}286{,}187$$

It follows that the expected value of the hedger's position, including the gain on the hedge, is

$$\$4{,}286{,}187 + \$810{,}000 = \$5{,}096{,}187$$

Table 6-4 summarizes these calculations together with similar calculations for other values of the index at maturity. It can be seen that the total expected value of the hedger's position in 3 months is almost independent of the value of the index.

The only thing we have not covered in this example is the relationship between futures prices and spot prices. We will see in Chapter 8 that the 1,010 assumed for the futures price today is roughly what we would expect given the interest rate and dividend we are assuming. The same is true of the futures prices in 3 months shown in Table 6-4.[5]

Reasons for Hedging an Equity Portfolio

Table 6-4 shows that the hedging procedure results in a value for the hedger's position at the end of the 3-month period being about 1% higher than at the beginning of the 3-month period. There is no surprise here. The risk-free rate is 4% per annum, or 1% per 3 months. The hedge results in the investor's position growing at the risk-free rate.

It is natural to ask why the hedger should go to the trouble of using futures contracts. To earn the risk-free interest rate, the hedger can simply sell the portfolio and invest the proceeds in a risk-free instrument.

One answer to this question is that hedging can be justified if the hedger feels that the stocks in the portfolio have been chosen well. In these circumstances, the hedger might be very uncertain about the performance of the market as a whole, but confident that the stocks in the portfolio will outperform the market (after appropriate adjustments have been made for the beta of the portfolio). A hedge using index futures removes the risk arising from market moves and leaves the hedger exposed only to the performance of the portfolio relative to the market. This will be discussed further shortly. Another reason for hedging may be that the hedger is planning to hold a portfolio for a long period of time and requires short-term protection in an uncertain market situation. The alternative strategy of selling the portfolio and buying it back later might involve unacceptably high transaction costs.

Changing the Beta of a Portfolio

In the example in Table 6-4, the beta of the hedger's portfolio is reduced to zero so that the hedger's expected

[5] The calculations in Table 6-4 assume that the dividend yield on the index is predictable, the risk-free interest rate remains constant, and the return on the index over the 3-month period is perfectly correlated with the return on the portfolio. In practice, these assumptions do not hold perfectly, and the hedge works rather less well than is indicated by Table 6-4.

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return is almost independent of the performance of the index.

Sometimes futures contracts are used to change the beta of a portfolio to some value other than zero. Continuing with our earlier example:

S&P 500 index = 1,000
S&P 500 futures price = 1,010
Value of portfolio = $5,050,000
Beta of portfolio = 1.5

As before, $V_F = 250 \times 1{,}010 = 252{,}500$ and a complete hedge requires

$$1.5 \times \frac{5{,}050{,}000}{252{,}500} = 30$$

contracts to be shorted. To reduce the beta of the portfolio from 1.5 to 0.75, the number of contracts shorted should be 15 rather than 30; to increase the beta of the portfolio to 2.0, a long position in 10 contracts should be taken; and so on. In general, to change the beta of the portfolio from β to β^*, where $\beta > \beta^*$, a short position in

$$(\beta - \beta^*)\frac{V_A}{V_F}$$

contracts is required. When $\beta < \beta^*$, a long position in

$$(\beta^* - \beta)\frac{V_A}{V_F}$$

contracts is required.

Locking In the Benefits of Stock Picking

Suppose you consider yourself to be good at picking stocks that will outperform the market. You own a single stock or a small portfolio of stocks. You do not know how well the market will perform over the next few months, but you are confident that your portfolio will do better than the market. What should you do?

You should short $\beta V_A / V_F$ index futures contracts, where β is the beta of your portfolio, V_A is the total value of the portfolio, and V_F is the current value of one index futures contract. If your portfolio performs better than a well-diversified portfolio with the same beta, you will then make money.

Consider an investor who in April holds 20,000 shares of a company, each worth $100. The investor feels that the market will be very volatile over the next three months but that the company has a good chance of outperforming the market. The investor decides to use the August futures contract on the S&P 500 to hedge the market's return during the three-month period. The β of the company's stock is estimated at 1.1. Suppose that the current futures price for the August contract on the S&P 500 is 1,500. Each contract is for delivery of $250 times the index. In this case, $V_A = 20{,}000 \times 100 = 2{,}000{,}000$ and $V_F = 1{,}500 \times 250 = 375{,}000$. The number of contracts that should be shorted is therefore

$$1.1 \times \frac{2{,}000{,}000}{375{,}000} = 5.87$$

Rounding to the nearest integer, the investor shorts 6 contracts, closing out the position in July. Suppose the company's stock price falls to $90 and the futures price of the S&P 500 falls to 1,300. The investor loses 20,000 × ($100 − $90) = $200,000 on the stock, while gaining 6 × 250 × (1,500 − 1,300) = $300,000 on the futures contracts.

The overall gain to the investor in this case is $100,000 because the company's stock price did not go down by as much as a well-diversified portfolio with a β of 1.1. If the market had gone up and the company's stock price went up by more than a portfolio with a β of 1.1 (as expected by the investor), then a profit would be made in this case as well.

STACK AND ROLL

Sometimes the expiration date of the hedge is later than the delivery dates of all the futures contracts that can be used. The hedger must then roll the hedge forward by closing out one futures contract and taking the same position in a futures contract with a later delivery date. Hedges can be rolled forward many times. The procedure is known as *stack and roll.* Consider a company that wishes to use a short hedge to reduce the risk associated with the price to be received for an asset at time T. If there are futures contracts 1, 2, 3, . . . , n (not all necessarily in existence at the present time) with progressively later delivery dates, the company can use the following strategy:

Time t_1: Short futures contract 1
Time t_2: Close out futures contract 1
Short futures contract 2
Time t_3: Close out futures contract 2
Short futures contract 3
⋮

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Time t_n: Close out futures contract $n - 1$
Short futures contract n

Time T: Close out futures contract n.

Suppose that in April 2014 a company realizes that it will have 100,000 barrels of oil to sell in June 2015 and decides to hedge its risk with a hedge ratio of 1.0. (In this example, we do not make the "tailing" adjustment.) The current spot price is $89. Although futures contracts are traded with maturities stretching several years into the future, we suppose that only the first six delivery months have sufficient liquidity to meet the company's needs. The company therefore shorts 100 October 2014 contracts. In September 2014, it rolls the hedge forward into the March 2015 contract. In February 2015, it rolls the hedge forward again into the July 2015 contract.

One possible outcome is shown in Table 6-5. The October 2014 contract is shorted at $88.20 per barrel and closed out at $87.40 per barrel for a profit of $0.80 per barrel; the March 2015 contract is shorted at $87.00 per barrel and closed out at $86.50 per barrel for a profit of $0.50 per barrel. The July 2015 contract is shorted at $86.30 per barrel and closed out at $85.90 per barrel for a profit of $0.40 per barrel. The final spot price is $86.

The dollar gain per barrel of oil from the short futures contracts is

$$(88.20 - 87.40) + (87.00 - 86.50) + (86.30 - 85.90) = 1.70$$

The oil price declined from $89 to $86. Receiving only $1.70 per barrel compensation for a price decline of $3.00 may appear unsatisfactory. However, we cannot expect total compensation for a price decline when futures prices are below spot prices. The best we can hope for is to lock in the futures price that would apply to a June 2015 contract if it were actively traded.

TABLE 6-5 Data for the Example on Rolling Oil Hedge Forward

Date	Apr. 2014	Sept. 2014	Feb. 2015	June 2015
Oct. 2014 futures price	88.20	87.40		
Mar. 2015 futures price		87.00	86.50	
July 2015 futures price			86.30	85.90
Spot price	89.00			86.00

In practice, a company usually has an exposure every month to the underlying asset and uses a 1-month futures contract for hedging because it is the most liquid. Initially it enters into ("stacks") sufficient contracts to cover its exposure to the end of its hedging horizon. One month later, it closes out all the contracts and "rolls" them into new 1-month contracts to cover its new exposure, and so on.

As described in Box 6-2, a German company, Metallgesellschaft, followed this strategy in the early 1990s to hedge contracts it had entered into to supply commodities at a fixed price. It ran into difficulties because the prices of the commodities declined so that there were immediate cash outflows on the futures and the expectation of eventual gains on the contracts. This mismatch between the timing of the cash flows on hedge and the timing of the cash flows from the position being hedged led to liquidity problems that could not be handled. The moral of the story is that potential liquidity problems should always be considered when a hedging strategy is being planned.

BOX 6-2 Metallgesellschaft: Hedging Gone Awry

Sometimes rolling hedges forward can lead to cash flow pressures. The problem was illustrated dramatically by the activities of a German company, Metallgesellschaft (MG), in the early 1990s.

MG sold a huge volume of 5- to 10-year heating oil and gasoline fixed-price supply contracts to its customers at 6 to 8 cents above market prices. It hedged its exposure with long positions in short-dated futures contracts that were rolled forward. As it turned out, the price of oil fell and there were margin calls on the futures positions. Considerable short-term cash flow pressures were placed on MG. The members of MG who devised the hedging strategy argued that these short-term cash outflows were offset by positive cash flows that would ultimately be realized on the long-term fixed-price contracts. However, the company's senior management and its bankers became concerned about the huge cash drain. As a result, the company closed out all the hedge positions and agreed with its customers that the fixed-price contracts would be abandoned. The outcome was a loss to MG of $1.33 billion.

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SUMMARY

This chapter has discussed various ways in which a company can take a position in futures contracts to offset an exposure to the price of an asset. If the exposure is such that the company gains when the price of the asset increases and loses when the price of the asset decreases, a short hedge is appropriate. If the exposure is the other way round (i.e., the company gains when the price of the asset decreases and loses when the price of the asset increases), a long hedge is appropriate.

Hedging is a way of reducing risk. As such, it should be welcomed by most executives. In reality, there are a number of theoretical and practical reasons why companies do not hedge. On a theoretical level, we can argue that shareholders, by holding well-diversified portfolios, can eliminate many of the risks faced by a company. They do not require the company to hedge these risks. On a practical level, a company may find that it is increasing rather than decreasing risk by hedging if none of its competitors does so. Also, a treasurer may fear criticism from other executives if the company makes a gain from movements in the price of the underlying asset and a loss on the hedge.

An important concept in hedging is basis risk. The basis is the difference between the spot price of an asset and its futures price. Basis risk arises from uncertainty as to what the basis will be at maturity of the hedge.

The hedge ratio is the ratio of the size of the position taken in futures contracts to the size of the exposure. It is not always optimal to use a hedge ratio of 1.0. If the hedger wishes to minimize the variance of a position, a hedge ratio different from 1.0 may be appropriate. The optimal hedge ratio is the slope of the best-fit line obtained when changes in the spot price are regressed against changes in the futures price.

Stock index futures can be used to hedge the systematic risk in an equity portfolio. The number of futures contracts required is the beta of the portfolio multiplied by the ratio of the value of the portfolio to the value of one futures contract. Stock index futures can also be used to change the beta of a portfolio without changing the stocks that make up the portfolio.

When there is no liquid futures contract that matures later than the expiration of the hedge, a strategy known as stack and roll may be appropriate. This involves entering into a sequence of futures contracts. When the first futures contract is near expiration, it is closed out and the hedger enters into a second contract with a later delivery month. When the second contract is close to expiration, it is closed out and the hedger enters into a third contract with a later delivery month; and so on. The result of all this is the creation of a long-dated futures contract by trading a series of short-dated contracts.

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APPENDIX

Capital Asset Pricing Model

The capital asset pricing model (CAPM) is a model that can be used to relate the expected return from an asset to the risk of the return. The risk in the return from an asset is divided into two parts. *Systematic risk* is risk related to the return from the market as a whole and cannot be diversified away. *Nonsystematic risk* is risk that is unique to the asset and can be diversified away by choosing a large portfolio of different assets. CAPM argues that the return should depend only on systematic risk. The CAPM formula is[6]

$$\text{Expected return on asset} = R_F + \beta(R_M - R_F) \qquad \textbf{(6.6)}$$

where R_M is the return on the portfolio of all available investments, R_F is the return on a risk-free investment, and β (the Greek letter beta) is a parameter measuring systematic risk.

The return from the portfolio of all available investments, R_M, is referred to as the *return on the market* and is usually approximated as the return on a well-diversified stock index such as the S&P 500. The beta (β) of an asset is a measure of the sensitivity of its returns to returns from the market. It can be estimated from historical data as the slope obtained when the excess return on the asset over the risk-free rate is regressed against the excess return on the market over the risk-free rate. When $\beta = 0$, an asset's returns are not sensitive to returns from the market. In this case, it has no systematic risk and Equation (6.6) shows that its expected return is the risk-free rate; when $\beta = 0.5$, the excess return on the asset over the risk-free rate is on average half of the excess return of the market over the risk-free rate; when $\beta = 1$, the expected return on the asset equals to the return on the market; and so on.

Suppose that the risk-free rate R_F is 5% and the return on the market is 13%. Equation (6.6) shows that, when the beta of an asset is zero, its expected return is 5%. When $\beta = 0.75$, its expected return is $0.05 + 0.75 \times (0.13 - 0.05) = 0.11$, or 11%.

The derivation of CAPM requires a number of assumptions.[7] In particular:

1. Investors care only about the expected return and standard deviation of the return from an asset.
2. The returns from two assets are correlated with each other only because of their correlation with the return from the market. This is equivalent to assuming that there is only one factor driving returns.
3. Investors focus on returns over a single period and that period is the same for all investors.
4. Investors can borrow and lend at the same risk-free rate.
5. Tax does not influence investment decisions.
6. All investors make the same estimates of expected returns, standard deviations of returns, and correlations between returns.

These assumptions are at best only approximately true. Nevertheless CAPM has proved to be a useful tool for

[6] If the return on the market is not known, R_M is replaced by the expected value of R_M in this formula.

[7] For details on the derivation, see, for example, J. Hull, *Risk Management and Financial Institutions*, 3rd ed. Hoboken, NJ: Wiley, 2012, Chap. 1.

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portfolio managers and is often used as a benchmark for assessing their performance.

When the asset is an individual stock, the expected return given by Equation (6.6) is not a particularly good predictor of the actual return. But, when the asset is a well-diversified portfolio of stocks, it is a much better predictor. As a result, the equation

$$\text{Return on diversified portfolio} = R_F + \beta(R_M - R_F)$$

can be used as a basis for hedging a diversified portfolio, as described in this chapter. The β in the equation is the beta of the portfolio. It can be calculated as the weighted average of the betas of the stocks in the portfolio.

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Interest Rates

7

Learning Objectives

After completing this reading you should be able to:

- Describe Treasury rates, LIBOR, and repo rates, and explain what is meant by the "risk-free" rate.
- Calculate the value of an investment using different compounding frequencies.
- Convert interest rates based on different compounding frequencies.
- Calculate the theoretical price of a bond using spot rates.
- Derive forward interest rates from a set of spot rates.
- Derive the value of the cash flows from a forward rate agreement (FRA).
- Calculate the duration, modified duration, and dollar duration of a bond.
- Evaluate the limitations of duration and explain how convexity addresses some of them.
- Calculate the change in a bond's price given its duration, its convexity, and a change in interest rates.
- Compare and contrast the major theories of the term structure of interest rates.

Excerpt is Chapter 4 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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Interest rates are a factor in the valuation of virtually all derivatives and will feature prominently in much of the material that will be presented in the rest of this book. This chapter deals with some fundamental issues concerned with the way interest rates are measured and analyzed. It explains the compounding frequency used to define an interest rate and the meaning of continuously compounded interest rates, which are used extensively in the analysis of derivatives. It covers zero rates, par yields, and yield curves, discusses bond pricing, and outlines a "bootstrap" procedure commonly used by a derivatives trading desk to calculate zero-coupon Treasury interest rates. It also covers forward rates and forward rate agreements and reviews different theories of the term structure of interest rates. Finally, it explains the use of duration and convexity measures to determine the sensitivity of bond prices to interest rate changes.

Chapter 9 will cover interest rate futures and show how the duration measure can be used when interest rate exposures are hedged. For ease of exposition, day count conventions will be ignored throughout this chapter. The nature of these conventions and their impact on calculations will be discussed in Chapters 9 and 10.

TYPES OF RATES

An interest rate in a particular situation defines the amount of money a borrower promises to pay the lender. For any given currency, many different types of interest rates are regularly quoted. These include mortgage rates, deposit rates, prime borrowing rates, and so on. The interest rate applicable in a situation depends on the credit risk. This is the risk that there will be a default by the borrower of funds, so that the interest and principal are not paid to the lender as promised. The higher the credit risk, the higher the interest rate that is promised by the borrower.

Interest rates are often expressed in basis points. One basis point is 0.01% per annum.

Treasury Rates

Treasury rates are the rates an investor earns on Treasury bills and Treasury bonds. These are the instruments used by a government to borrow in its own currency. Japanese Treasury rates are the rates at which the Japanese government borrows in yen; US Treasury rates are the rates at which the US government borrows in US dollars; and so on. It is usually assumed that there is no chance that a government will default on an obligation denominated in its own currency. Treasury rates are therefore totally risk-free rates in the sense that an investor who buys a Treasury bill or Treasury bond is certain that interest and principal payments will be made as promised.

LIBOR

LIBOR is short for *London Interbank Offered Rate*. It is an unsecured short-term borrowing rate between banks. LIBOR rates have traditionally been calculated each business day for 10 currencies and 15 borrowing periods. The borrowing periods range from one day to one year. LIBOR rates are used as reference rates for hundreds of trillions of dollars of transactions throughout the world. One popular derivatives transaction that uses LIBOR as a reference interest rate is an interest rate swap (see Chapter 10). LIBOR rates are published by the British Bankers Association (BBA) at 11:30 a.m. (UK time). The BBA asks a number of different banks to provide quotes estimating the rate of interest at which they could borrow funds just prior to 11:00 a.m. (UK time). The top quarter and bottom quarter of the quotes for each currency/borrowing-period combination are discarded and the remaining ones are averaged to determine the LIBOR fixings for a day. Typically the banks submitting quotes have a AA credit rating.[1] LIBOR is therefore usually considered to be an estimate of the short-term unsecured borrowing rate for a AA-rated financial institution.

In recent years there have been suggestions that some banks may have manipulated their LIBOR quotes. Two reasons have been suggested for manipulation. One is to make the banks' borrowing costs seem lower than they actually are, so that they appear healthier. Another is to profit from transactions such as interest rate swaps whose cash flows depend on LIBOR fixings. The underlying problem is that there is not enough interbank borrowing for banks to make accurate estimates of their borrowing rates for all the different currency/borrowing-period combinations that are used. It seems likely that over time the large number of LIBOR quotes that have been provided each day will be replaced by a smaller number of quotes based on actual transactions in a more liquid market.

[1] The best credit rating category is AAA. The second best is AA.

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The Fed Funds Rate

In the United States, financial institutions are required to maintain a certain amount of cash (known as reserves) with the Federal Reserve. The reserve requirement for a bank at any time depends on its outstanding assets and liabilities. At the end of a day, some financial institutions typically have surplus funds in their accounts with the Federal Reserve while others have requirements for funds. This leads to borrowing and lending overnight. In the United States, the overnight rate is called the *federal funds rate*. A broker usually matches borrowers and lenders. The weighted average of the rates in brokered transactions (with weights being determined by the size of the transaction) is termed the *effective federal funds rate*. This overnight rate is monitored by the central bank, which may intervene with its own transactions in an attempt to raise or lower it. Other countries have similar systems to the US. For example, in the UK the average of brokered overnight rates is termed the sterling overnight index average (SONIA) and, in the euro zone, it is termed the euro overnight index average (EONIA).

Both LIBOR and the federal funds rate are unsecured borrowing rates. On average, overnight LIBOR has been about 6 basis points (0.06%) higher than the effective federal funds rate except for the tumultuous period from August 2007 to December 2008. The observed differences between the rates can be attributed to timing effects, the composition of the pool of borrowers in London as compared to New York, and differences between the settlement mechanisms in London and New York.[2]

Repo Rates

Unlike LIBOR and federal funds rates, repo rates are secured borrowing rates. In a repo (or repurchase agreement), a financial institution that owns securities agrees to sell the securities for a certain price and buy them back at a later time for a slightly higher price. The financial institution is obtaining a loan and the interest it pays is the difference between the price at which the securities are sold and the price at which they are repurchased. The interest rate is referred to as the *repo rate*.

If structured carefully, a repo involves very little credit risk. If the borrower does not honor the agreement, the lending company simply keeps the securities. If the lending company does not keep to its side of the agreement, the original owner of the securities keeps the cash provided by the lending company. The most common type of repo is an *overnight repo* which may be rolled over day to day. However, longer term arrangements, known as *term repos*, are sometimes used. Because they are secured rates, a repo rate is generally slightly below the corresponding fed funds rate.

The "Risk-Free" Rate

Derivatives are usually valued by setting up a riskless portfolio and arguing that the return on the portfolio should be the risk-free interest rate. The risk-free interest rate therefore plays a key role in the valuation of derivatives. For most of this book we will refer to the "risk-free" rate without explicitly defining which rate we are referring to. This is because derivatives practitioners use a number of different proxies for the risk-free rate. Traditionally LIBOR has been used as the risk-free rate—even though LIBOR is not risk-free because there is some small chance that a AA-rated financial institution will default on a short-term loan. However, this is changing.

MEASURING INTEREST RATES

A statement by a bank that the interest rate on one-year deposits is 10% per annum sounds straightforward and unambiguous. In fact, its precise meaning depends on the way the interest rate is measured.

If the interest rate is measured with annual compounding, the bank's statement that the interest rate is 10% means that $100 grows to

$$\$100 \times 1.1 = \$110$$

at the end of 1 year. When the interest rate is measured with semiannual compounding, it means that 5% is earned every 6 months, with the interest being reinvested. In this case, $100 grows to

$$\$100 \times 1.05 \times 1.05 = \$110.25$$

at the end of 1 year. When the interest rate is measured with quarterly compounding, the bank's statement means

[2] See L. Bartolini, S. Hilton, and A. Prati, "Money Market Integration," *Journal of Money, Credit and Banking*, 40, 1 (February 2008), 193–213.

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TABLE 7-1 Effect of the Compounding Frequency on the Value of $100 at the End of 1 Year When the Interest Rate Is 10% per Annum

Compounding Frequency	Value of $100 at End of Year ($)
Annually ($m = 1$)	110.00
Semiannually ($m = 2$)	110.25
Quarterly ($m = 4$)	110.38
Monthly ($m = 12$)	110.47
Weekly ($m = 52$)	110.51
Daily ($m = 365$)	110.52

that 2.5% is earned every 3 months, with the interest being reinvested. The $100 then grows to

$$\$100 \times 1.025^4 = \$110.38$$

at the end of 1 year. Table 7-1 shows the effect of increasing the compounding frequency further.

The compounding frequency defines the units in which an interest rate is measured. A rate expressed with one compounding frequency can be converted into an equivalent rate with a different compounding frequency. For example, from Table 7-1 we see that 10.25% with annual compounding is equivalent to 10% with semiannual compounding. We can think of the difference between one compounding frequency and another to be analogous to the difference between kilometers and miles. They are two different units of measurement.

To generalize our results, suppose that an amount A is invested for n years at an interest rate of R per annum. If the rate is compounded once per annum, the terminal value of the investment is

$$A(1 + R)^n$$

If the rate is compounded m times per annum, the terminal value of the investment is

$$A\left(1+\frac{R}{m}\right)^{mn} \tag{7.1}$$

When $m = 1$, the rate is sometimes referred to as the *equivalent annual interest rate*.

Continuous Compounding

The limit as the compounding frequency, m, tends to infinity is known as *continuous compounding*.[3] With continuous compounding, it can be shown that an amount A invested for n years at rate R grows to

$$Ae^{Rn} \tag{7.2}$$

where e is approximately 2.71828. The exponential function, e^x, is built into most calculators, so the computation of the expression in Equation (7.2) presents no problems. In the example in Table 7-1, $A = 100$, $n = 1$, and $R = 0.1$, so that the value to which A grows with continuous compounding is

$$100e^{0.1} = \$110.52$$

This is (to two decimal places) the same as the value with daily compounding. For most practical purposes, continuous compounding can be thought of as being equivalent to daily compounding. Compounding a sum of money at a continuously compounded rate R for n years involves multiplying it by e^{Rn}. Discounting it at a continuously compounded rate R for n years involves multiplying by e^{-Rn}.

In this book, interest rates will be measured with continuous compounding except where stated otherwise. Readers used to working with interest rates that are measured with annual, semiannual, or some other compounding frequency may find this a little strange at first. However, continuously compounded interest rates are used to such a great extent in pricing derivatives that it makes sense to get used to working with them now.

Suppose that R_c is a rate of interest with continuous compounding and R_m is the equivalent rate with compounding m times per annum. From the results in Equations (7.1) and (7.2), we have

$$Ae^{R_c n} = A\left(1+\frac{R_m}{m}\right)^{mn}$$

or

$$e^{R_c} = \left(1+\frac{R_m}{m}\right)^m$$

[3] Actuaries sometimes refer to a continuously compounded rate as the *force of interest*.

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This means that

$$R_c = m \ln\left(1+\frac{R_m}{m}\right) \tag{7.3}$$

and

$$R_m = m\left(e^{R_c/m}-1\right) \tag{7.4}$$

These equations can be used to convert a rate with a compounding frequency of m times per annum to a continuously compounded rate and vice versa. The natural logarithm function ln x, which is built into most calculators, is the inverse of the exponential function, so that, if $y = \ln x$, then $x = e^y$.

Example 7.1

Consider an interest rate that is quoted as 10% per annum with semiannual compounding. From Equation (7.3) with $m = 2$ and $R_m = 0.1$, the equivalent rate with continuous compounding is

$$2 \ln\left(1+\frac{0.1}{2}\right) = 0.09758$$

or 9.758% per annum.

Example 7.2

Suppose that a lender quotes the interest rate on loans as 8% per annum with continuous compounding, and that interest is actually paid quarterly. From Equation (7.4) with $m = 4$ and $R_c = 0.08$, the equivalent rate with quarterly compounding is

$$4 \times \left(e^{0.08/4}-1\right) = 0.0808$$

or 8.08% per annum. This means that on a $1,000 loan, interest payments of $20.20 would be required each quarter.

ZERO RATES

The n-year zero-coupon interest rate is the rate of interest earned on an investment that starts today and lasts for n years. All the interest and principal is realized at the end of n years. There are no intermediate payments. The n-year zero-coupon interest rate is sometimes also referred to as the n-year *spot rate*, the n-year *zero rate*, or just the n-year zero. Suppose a 5-year zero rate with continuous compounding is quoted as 5% per annum. This means that $100, if invested for 5 years, grows to

$$100 \times e^{0.05 \times 5} = 128.40$$

Most of the interest rates we observe directly in the market are not pure zero rates. Consider a 5-year government bond that provides a 6% coupon. The price of this bond does not by itself determine the 5-year Treasury zero rate because some of the return on the bond is realized in the form of coupons prior to the end of year 5. Later in this chapter we will discuss how we can determine Treasury zero rates from the market prices of coupon-bearing bonds.

BOND PRICING

Most bonds pay coupons to the holder periodically. The bond's principal (which is also known as its par value or face value) is paid at the end of its life. The theoretical price of a bond can be calculated as the present value of all the cash flows that will be received by the owner of the bond. Sometimes bond traders use the same discount rate for all the cash flows underlying a bond, but a more accurate approach is to use a different zero rate for each cash flow.

To illustrate this, consider the situation where Treasury zero rates, measured with continuous compounding, are as in Table 7-2. (We explain later how these can be calculated.) Suppose that a 2-year Treasury bond with a principal of $100 provides coupons at the rate of 6% per annum semiannually. To calculate the present value of the first coupon of $3, we discount it at 5.0% for 6 months; to calculate the present value of the second coupon of $3, we discount it at 5.8% for 1 year; and so on. Therefore, the theoretical price of the bond is

$$3e^{-0.05 \times 0.5} + 3e^{-0.058 \times 1.0} + 3e^{-0.064 \times 1.5} + 103e^{-0.068 \times 2.0} = 98.39$$

or $98.39.

Bond Yield

A bond's yield is the single discount rate that, when applied to all cash flows, gives a bond price equal to its market price. Suppose that the theoretical price of the bond we have been considering, $98.39, is also its market value (i.e., the market's price of the bond is in exact

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TABLE 7-2 Treasury Zero Rates

Maturity (years)	Zero Rate (%) (continuously compounded)
0.5	5.0
1.0	5.8
1.5	6.4
2.0	6.8

agreement with the data in Table 7-2). If y is the yield on the bond, expressed with continuous compounding, it must be true that

$$3e^{-y\times 0.5} + 3e^{-y\times 1.0} + 3e^{-y\times 1.5} + 103e^{-y\times 2.0} = 98.39$$

This equation can be solved using an iterative ("trial and error") procedure to give $y = 6.76\%$.[4]

Par Yield

The *par yield* for a certain bond maturity is the coupon rate that causes the bond price to equal its par value. (The par value is the same as the principal value.) Usually the bond is assumed to provide semiannual coupons. Suppose that the coupon on a 2-year bond in our example is c per annum (or ½ c per 6 months). Using the zero rates in Table 7-2, the value of the bond is equal to its par value of 100 when

$$\frac{c}{2}e^{-0.05\times 0.5} + \frac{c}{2}e^{-0.058\times 1.0} + \frac{c}{2}e^{-0.064\times 1.5} + \left(100 + \frac{c}{2}\right)e^{-0.068\times 2.0} = 100$$

This equation can be solved in a straightforward way to give $c = 6.87$. The 2-year par yield is therefore 6.87% per annum. This has semiannual compounding because payments are assumed to be made every 6 months. With continuous compounding, the rate is 6.75% per annum.

More generally, if d is the present value of \$1 received at the maturity of the bond, A is the value of an annuity that pays one dollar on each coupon payment date, and m is the number of coupon payments per year, then the par yield c must satisfy

$$100 = A\frac{c}{m} + 100d$$

so that

$$c = \frac{(100 - 100d)m}{A}$$

In our example, $m = 2$, $d = e^{-0.068\times 2} = 0.87284$, and

$$A = e^{-0.05\times 0.5} + e^{-0.058\times 1.0} + e^{-0.064\times 1.5} + e^{-0.068\times 2.0} = 3.70027$$

The formula confirms that the par yield is 6.87% per annum.

DETERMINING TREASURY ZERO RATES

One way of determining Treasury zero rates such as those in Table 7-2 is to observe the yields on "strips." These are zero-coupon bonds that are synthetically created by traders when they sell coupons on a Treasury bond separately from the principal.

Another way to determine Treasury zero rates is from Treasury bills and coupon-bearing bonds. The most popular approach is known as the *bootstrap method*. To illustrate the nature of the method, consider the data in Table 7-3 on the prices of five bonds. Because the first three bonds pay no coupons, the zero rates corresponding to the maturities of these bonds can easily be calculated. The 3-month bond has the effect of turning an investment of 97.5 into 100 in 3 months. The continuously compounded 3-month rate R is therefore given by solving

$$100 = 97.5e^{R\times 0.25}$$

It is 10.127% per annum. The 6-month continuously compounded rate is similarly given by solving

$$100 = 94.9e^{R\times 0.5}$$

It is 10.469% per annum. Similarly, the 1-year rate with continuous compounding is given by solving

$$100 = 90e^{R\times 1.0}$$

It is 10.536% per annum.

The fourth bond lasts 1.5 years. The payments are as follows:

6 months:	\$4
1 year:	\$4
1.5 years:	\$104.

[4] One way of solving nonlinear equations of the form $f(y) = 0$, such as this one, is to use the Newton–Raphson method. We start with an estimate y_0 of the solution and produce successively better estimates $y_1, y_2, y_3, \ldots$ using the formula $y_{i+1} = y_i - f(y_i)/f'(y_i)$, where $f'(y_i)$ denotes the derivative of f with respect to y.

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TABLE 7-3 Data for Bootstrap Method

Bond Principal ($)	Time to Maturity (years)	Annual Coupon* ($)	Bond Price ($)
100	0.25	0	97.5
100	0.50	0	94.9
100	1.00	0	90.0
100	1.50	8	96.0
100	2.00	12	101.6

*Half the stated coupon is assumed to be paid every 6 months.

From our earlier calculations, we know that the discount rate for the payment at the end of 6 months is 10.469% and that the discount rate for the payment at the end of 1 year is 10.536%. We also know that the bond's price, $96, must equal the present value of all the payments received by the bondholder. Suppose the 1.5-year zero rate is denoted by R. It follows that

$$4e^{-0.10469\times0.5} + 4e^{-0.10536\times1.0} + 104e^{-R\times1.5} = 96$$

This reduces to

$$e^{-1.5R} = 0.85196$$

or

$$R = \frac{\ln(0.85196)}{1.5} = 0.10681$$

The 1.5-year zero rate is therefore 10.681%. This is the only zero rate that is consistent with the 6-month rate, 1-year rate, and the data in Table 7-3.

The 2-year zero rate can be calculated similarly from the 6-month, 1-year, and 1.5-year zero rates, and the information on the last bond in Table 7-3. If R is the 2-year zero rate, then

$$6e^{-0.10469\times0.5} + 6e^{-0.10536\times1.0} + 6e^{-0.10681\times1.5} + 106e^{-R\times2.0} = 101.6$$

This gives $R = 0.10808$, or 10.808%.

The rates we have calculated are summarized in Table 7-4. A chart showing the zero rate as a function of maturity is known as the *zero curve*. A common assumption is that the zero curve is linear between the points determined using the bootstrap method. (This means that the 1.25-year zero rate is $0.5 \times 10.536 + 0.5 \times 10.681 = 10.6085\%$ in our example.) It is also usually assumed that the zero curve is horizontal prior to the first point and horizontal beyond the last point. Figure 7-1 shows the zero curve for our data using these assumptions. By using longer maturity bonds, the zero curve would be more accurately determined beyond 2 years.

TABLE 7-4 Continuously Compounded Zero Rates Determined from Data in Table 7-3

Maturity (years)	Zero Rate (%) (continuously compounded)
0.25	10.127
0.50	10.469
1.00	10.536
1.50	10.681
2.00	10.808

In practice, we do not usually have bonds with maturities equal to exactly 1.5 years, 2 years, 2.5 years, and so on. The approach often used by analysts is to interpolate between the bond price data before it is used to calculate the zero curve. For example, if it is known that a 2.3-year bond with a coupon of 6% sells for 98 and a 2.7-year bond with a coupon of 6.5% sells for 99, it might be assumed that a 2.5-year bond with a coupon of 6.25% would sell for 98.5.

FORWARD RATES

Forward interest rates are the future rates of interest implied by current zero rates for periods of time in the future. To illustrate how they are calculated, we suppose that zero rates are as shown in the second column of Table 7-5. The rates are assumed to be continuously compounded. Thus, the 3% per annum rate for 1 year means that, in return for an investment of $100 today, an amount $100e^{0.03\times1} = \$103.05$ is received in 1 year; the 4% per annum rate for 2 years means that, in return for an investment of $100 today, an amount $100e^{0.04\times2} = \$108.33$ is received in 2 years; and so on.

The forward interest rate in Table 7-5 for year 2 is 5% per annum. This is the rate of interest that is implied by the zero rates for the period of time between the end of the first year and the end of the second year. It can be calculated from the 1-year zero interest rate of 3% per annum

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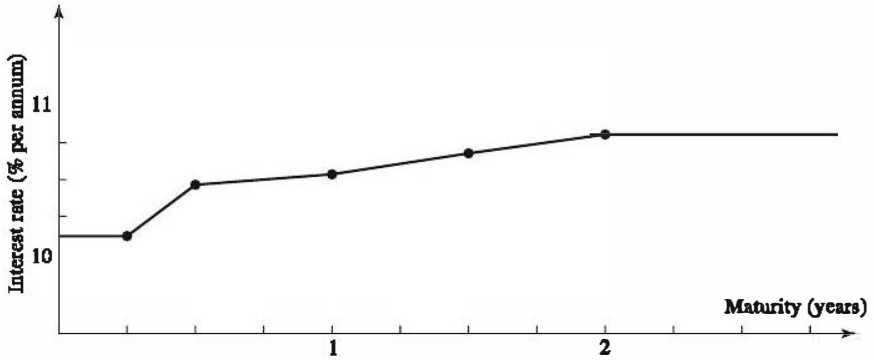

FIGURE 7-1 Zero rates given by the bootstrap method.

and the 2-year zero interest rate of 4% per annum. It is the rate of interest for year 2 that, when combined with 3% per annum for year 1, gives 4% overall for the 2 years. To show that the correct answer is 5% per annum, suppose that \$100 is invested. A rate of 3% for the first year and 5% for the second year gives

$$100e^{0.03\times1}e^{0.05\times1} = \$108.33$$

at the end of the second year. A rate of 4% per annum for 2 years gives

$$100e^{0.04\times2}$$

which is also \$108.33. This example illustrates the general result that when interest rates are continuously compounded and rates in successive time periods are combined, the overall equivalent rate is simply the average rate during the whole period. In our example, 3% for the first year and 5% for the second year average to 4% over the 2 years. The result is only approximately true when the rates are not continuously compounded.

The forward rate for year 3 is the rate of interest that is implied by a 4% per annum 2-year zero rate and a 4.6% per annum 3-year zero rate. It is 5.8% per annum. The reason is that an investment for 2 years at 4% per annum combined with an investment for one year at 5.8% per annum gives an overall average return for the three years of 4.6% per annum. The other forward rates can be calculated similarly and are shown in the third column of the table. In general, if R_1 and R_2 are the zero rates for maturities T_1 and T_2, respectively, and R_F is the forward interest rate for the period of time between T_1 and T_2, then

$$R_F = \frac{R_2T_2 - R_1T_1}{T_2 - T_1} \tag{7.5}$$

To illustrate this formula, consider the calculation of the year-4 forward rate from the data in Table 7-5: $T_1 = 3$, $T_2 = 4$, $R_1 = 0.046$, and $R_2 = 0.05$, and the formula gives $R_F = 0.062$.

Equation (7.5) can be written as

$$R_F = R_2 + (R_2 - R_1)\frac{T_1}{T_2 - T_1} \tag{7.8}$$

This shows that, if the zero curve is upward sloping between T_1 and T_2 so that $R_2 > R_1$, then $R_F > R_2$ (i.e., the forward rate for a period of time ending at T_2 is greater than the T_2 zero rate). Similarly, if the zero curve is downward sloping with $R_2 < R_1$, then $R_F < R_2$ (i.e., the forward rate is less than the T_2 zero rate). Taking limits as T_2 approaches T_1 in Equation (7.6) and letting the common value of the two be T, we obtain

$$R_F = R + T\frac{\partial R}{\partial T}$$

where R is the zero rate for a maturity of T. The value of R_F obtained in this way is known as the *instantaneous forward rate* for a maturity of T. This is the forward rate that is applicable to a very short future time period that begins at time T. Define $P(0, T)$ as the price of a zero-coupon bond maturing at time T. Because $P(0, T) = e^{-RT}$, the equation for the instantaneous forward rate can also be written as

$$R_F = -\frac{\partial}{\partial T}\ln P(0,T)$$

If a large financial institution can borrow or lend at the rates in Table 7-5, it can lock in the forward rates. For example, it can borrow \$100 at 3% for 1 year and invest the money at 4% for 2 years, the result is a cash outflow of $100e^{0.03\times1} = \$103.05$ at the end of year 1 and an inflow of $100e^{0.04\times2} = \$108.33$ at the end of year 2. Since $108.33 = 103.05e^{0.05}$, a return equal to the forward rate (5%) is earned on \$103.05 during the second year.

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TABLE 7-5 Calculation of Forward Rates

Year (n)	Zero Rate for an *n*-year Investment (% per annum)	Forward Rate for *n*th Year (% per annum)
1	3.0	
2	4.0	5.0
3	4.6	5.8
4	5.0	6.2
5	5.3	6.5

Alternatively, it can borrow $100 for four years at 5% and invest it for three years at 4.6%. The result is a cash inflow of $100e^{0.046\times3} = \$114.80$ at the end of the third year and a cash outflow of $100e^{0.05\times4} = \$122.14$ at the end of the fourth year. Since $122.14 = 114.80e^{0.062}$, money is being borrowed for the fourth year at the forward rate of 6.2%.

If a large investor thinks that rates in the future will be different from today's forward rates, there are many trading strategies that the investor will find attractive (see Box 7-1). One of these involves entering into a contract known as a *forward rate agreement*. We will now discuss how this contract works and how it is valued.

FORWARD RATE AGREEMENTS

A forward rate agreement (FRA) is an over-the-counter transaction designed to fix the interest rate that will apply to either borrowing or lending a certain principal during a specified future period of time. The usual assumption underlying the contract is that the borrowing or lending would normally be done at LIBOR.

If the agreed fixed rate is greater than the actual LIBOR rate for the period, the borrower pays the lender the difference between the two applied to the principal. If the reverse is true, the lender pays the borrower the difference applied to the principal. Because interest is paid in arrears, the payment of the interest rate differential is due at the end of the specified period of time. Usually, however, the present value of the payment is made at the beginning of the specified period, as illustrated in Example 7.3.

BOX 7-1 Orange County's Yield Curve Plays

Suppose a large investor can borrow or lend at the rates given in Table 7-5 and thinks that 1-year interest rates will not change much over the next 5 years. The investor can borrow 1-year funds and invest for 5 years. The 1-year borrowings can be rolled over for further 1-year periods at the end of the first, second, third, and fourth years. If interest rates do stay about the same, this strategy will yield a profit of about 2.3% per year, because interest will be received at 5.3% and paid at 3%. This type of trading strategy is known as a *yield curve play*. The investor is speculating that rates in the future will be quite different from the forward rates observed in the market today. (In our example, forward rates observed in the market today for future 1-year periods are 5%, 5.8%, 6.2%, and 6.5%.)

Robert Citron, the Treasurer at Orange County, used yield curve plays similar to the one we have just described very successfully in 1992 and 1993. The profit from Mr. Citron's trades became an important contributor to Orange County's budget and he was re-elected. (No one listened to his opponent in the election, who said his trading strategy was too risky.)

In 1994 Mr. Citron expanded his yield curve plays. He invested heavily in *inverse floaters*. These pay a rate of interest equal to a fixed rate of interest minus a floating rate. He also leveraged his position by borrowing in the repo market. If short-term interest rates had remained the same or declined he would have continued to do well. As it happened, interest rates rose sharply during 1994. On December 1, 1994, Orange County announced that its investment portfolio had lost $1.5 billion and several days later it filed for bankruptcy protection.

Example 7.3

Suppose that a company enters into an FRA that is designed to ensure it will receive a fixed rate of 4% on a principal of $100 million for a 3-month period starting in 3 years. The FRA is an exchange where LIBOR is paid and 4% is received for the 3-month period. If 3-month LIBOR proves to be 4.5% for the 3-month period, the cash flow to the lender will be

$$100{,}000{,}000 \times (0.04 - 0.045) \times 0.25 = -\$125{,}000$$

at the 3.25-year point. This is equivalent to a cash flow of

$$-\frac{125{,}000}{1 + 0.045 \times 0.25} = -\$123{,}609$$

at the 3-year point. The cash flow to the party on the opposite side of the transaction will be +$125,000 at the

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3.25-year point or +$123,609 at the 3-year point. (All interest rates in this example are expressed with quarterly compounding.)

Consider an FRA where company X is agreeing to lend money to company Y for the period of time between T_1 and T_2. Define:

R_K: The fixed rate of interest agreed to in the FRA

R_F: The forward LIBOR interest rate for the period between times T_1 and T_2, calculated today[5]

R_M: The actual LIBOR interest rate observed in the market at time T_1 for the period between times T_1 and T_2

L: The principal underlying the contract.

We will depart from our usual assumption of continuous compounding and assume that the rates R_K, R_F, and R_M are all measured with a compounding frequency reflecting the length of the period to which they apply. This means that if $T_2 - T_1 = 0.5$, they are expressed with semiannual compounding; if $T_2 - T_1 = 0.25$, they are expressed with quarterly compounding; and so on. (This assumption corresponds to the usual market practice for FRAs.)

Normally company X would earn R_M from the LIBOR loan. The FRA means that it will earn R_K. The extra interest rate (which may be negative) that it earns as a result of entering into the FRA is $R_K - R_M$. The interest rate is set at time T_1 and paid at time T_2. The extra interest rate therefore leads to a cash flow to company X at time T_2 of

$$L(R_K - R_M)(T_2 - T_1) \tag{7.7}$$

Similarly there is a cash flow to company Y at time T_2 of

$$L(R_M - R_K)(T_2 - T_1) \tag{7.8}$$

From Equations (7.7) and (7.8), we see that there is another interpretation of the FRA. It is an agreement where company X will receive interest on the principal between T_1 and T_2 at the fixed rate of R_K and pay interest at the realized LIBOR rate of R_M. Company Y will pay interest on the principal between T_1 and T_2 at the fixed rate of R_K and receive interest at R_M. This interpretation of an FRA will be important when we consider interest rate swaps in Chapter 10.

[5] The calculation of forward LIBOR rates is discussed in Chapter 10.

As mentioned, FRAs are usually settled at time T_1 rather than T_2. The payoff must then be discounted from time T_2 to T_1. For company X, the payoff at time T_1 is

$$\frac{L(R_K - R_M)(T_2 - T_1)}{1 + R_M(T_2 - T_1)}$$

and, for company Y, the payoff at time T_1 is

$$\frac{L(R_M - R_K)(T_2 - T_1)}{1 + R_M(T_2 - T_1)}$$

Valuation

An FRA is worth zero when the fixed rate R_K equals the forward rate R_F.[6] When it is first entered into R_K is set equal to the current value of R_F, so that the value of the contract to each side is zero.[7] As time passes, interest rates change, so that the value is no longer zero.

The market value of a derivative at a particular time is referred to as its *mark-to-market*, or MTM, value. To calculate the MTM value of an FRA where the fixed rate of interest is being received, we imagine a portfolio consisting of two FRAs. The first FRA states that R_K will be received on a principal of L between times T_1 and T_2. The second FRA states that R_F will be paid on a principal of L between times T_1 and T_2. The payoff from the first FRA at time T_2 is $L(R_K - R_M)(T_2 - T_1)$ and the payoff from the second FRA at time T_2 is $L(R_M - R_F)(T_2 - T_1)$. The total payoff is $L(R_K - R_F)(T_2 - T_1)$ and is known for certain today. The portfolio is therefore a risk-free investment and its value today is the payoff at time T_2 discounted at the risk-free rate or

$$L(R_K - R_F)(T_2 - T_1)e^{-R_2T_2}$$

[6] This can be regarded as the definition of what we mean by forward LIBOR. In an idealized situation where a bank can borrow or lend at LIBOR, it can artificially create a contract where it earns or pays forward LIBOR, as shown in the previous section. For example, it can ensure that it earns a forward rate between years 2 and 3 by borrowing a certain amount of money for 2 years and investing it for 3 years. Similarly, it can ensure that it pays a forward rate between years 2 and 3 by borrowing a certain amount of money for 3 years and lending it for 2 years.

[7] In practice, this is not quite true. A market maker such as a bank will quote a bid and offer for R_K, the bid corresponding to the situation where it is paying R_K and the offer corresponding to the situation where it is receiving R_K. An FRA at inception will therefore have a small positive value to the bank and a small negative value to its counterparty.

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where R_2 is the continuously compounded riskless zero rate for a maturity T_2.[8] Because the value of the second FRA, where R_F is paid, is zero, the value of the first FRA, where R_K is received, must be

$$V_{FRA} = L(R_K - R_F)(T_2 - T_1)e^{-R_2T_2} \quad (7.9)$$

Similarly, the value of an FRA where R_K is paid is

$$V_{FRA} = L(R_F - R_K)(T_2 - T_1)e^{-R_2T_2} \quad (7.10)$$

By comparing Equations (7.7) and (7.9), or Equations (7.8) and (7.10), we see that an FRA can be valued if we:

1. Calculate the payoff on the assumption that forward rates are realized (that is, on the assumption that $R_M = R_F$).
2. Discount this payoff at the risk-free rate.

We will use this result when we value swaps (which are portfolios of FRAs) in Chapter 10.

Example 7.4

Suppose that the forward LIBOR rate for the period between time 1.5 years and time 2 years in the future is 5% (with semiannual compounding) and that some time ago a company entered into an FRA where it will receive 5.8% (with semiannual compounding) and pay LIBOR on a principal of $100 million for the period. The 2-year risk-free rate is 4% (with continuous compounding). From Equation (7.9), the value of the FRA is

$$100{,}000{,}000 \times (0.058 - 0.050) \times 0.5e^{-0.04\times 2} = \$369{,}200$$

DURATION

The *duration* of a bond, as its name implies, is a measure of how long on average the holder of the bond has to wait before receiving cash payments. A zero-coupon bond that lasts n years has a duration of n years. However, a coupon-bearing bond lasting n years has a duration of less than n years, because the holder receives some of the cash payments prior to year n.

Suppose that a bond provides the holder with cash flows c_i at time t_i ($1 \le i \le n$). The bond price B and bond yield y (continuously compounded) are related by

$$B = \sum_{i=1}^{n} c_i e^{-yt_i} \quad (7.11)$$

[8] Note that R_K, R_M, and R_F are expressed with a compounding frequency corresponding to $T_2 - T_1$, whereas R_2 is expressed with continuous compounding.

The duration of the bond, D, is defined as

$$D = \frac{\sum_{i=1}^{n} t_i c_i e^{-yt_i}}{B} \quad (7.12)$$

This can be written

$$D = \sum_{i=1}^{n} t_i \left[\frac{c_i e^{-yt_i}}{B}\right]$$

The term in square brackets is the ratio of the present value of the cash flow at time t_i to the bond price. The bond price is the present value of all payments. The duration is therefore a weighted average of the times when payments are made, with the weight applied to time t_i being equal to the proportion of the bond's total present value provided by the cash flow at time t_i. The sum of the weights is 1.0. Note that, for the purposes of the definition of duration, all discounting is done at the bond yield rate of interest, y. (We do not use a different zero rate for each cash flow in the way described earlier.)

When a small change Δy in the yield is considered, it is approximately true that

$$\Delta B = \frac{dB}{dy}\Delta y \quad (7.13)$$

From Equation (7.11), this becomes

$$\Delta B = -\Delta y \sum_{i=1}^{n} c_i t_i e^{-yt_i} \quad (7.14)$$

(Note that there is a negative relationship between B and y. When bond yields increase, bond prices decrease. When bond yields decrease, bond prices increase.) From Equations (7.12) and (7.14), the key duration relationship is obtained:

$$\Delta B = -BD\Delta y \quad (7.15)$$

This can be written

$$\frac{\Delta B}{B} = -D\Delta y \quad (7.16)$$

Equation (7.16) is an approximate relationship between percentage changes in a bond price and changes in its yield. It is easy to use and is the reason why duration, first suggested by Frederick Macaulay in 1938, has become such a popular measure.

Consider a 3-year 10% coupon bond with a face value of $100. Suppose that the yield on the bond is 12% per annum with continuous compounding. This means that

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TABLE 7-6 Calculation of Duration

Time (years)	Cash Flow($)	Present Value	Weight	Time × Weight
0.5	5	4.709	0.050	0.025
1.0	5	4.435	0.047	0.047
1.5	5	4.176	0.044	0.066
2.0	5	3.933	0.042	0.083
2.5	5	3.704	0.039	0.098
3.0	105	73.256	0.778	2.333
Total:	130	94.213	1.000	2.653

$y = 0.12$. Coupon payments of $5 are made every 6 months. Table 7-6 shows the calculations necessary to determine the bond's duration. The present values of the bond's cash flows, using the yield as the discount rate, are shown in column 3 (e.g., the present value of the first cash flow is $5e^{-0.12\times0.5} = 4.709$). The sum of the numbers in column 3 gives the bond's price as 94.213. The weights are calculated by dividing the numbers in column 3 by 94.213. The sum of the numbers in column 5 gives the duration as 2.653 years.

DV01 is the price change from a 1-basis-point increase in all rates. Gamma is the change in DV01 from a 1-basis-point increase in all rates. The following example investigates the accuracy of the duration relationship in Equation (7.15).

Example 7.5

For the bond in Table 7-6, the bond price, B, is 94.213 and the duration, D, is 2.653, so that Equation (7.15) gives

$$\Delta B = -94.213 \times 2.653 \times \Delta y$$

or

$$\Delta B = -249.95 \times \Delta y$$

When the yield on the bond increases by 10 basis points (= 0.1%), $\Delta y = +0.001$. The duration relationship predicts that $\Delta B = -249.95 \times 0.001 = -0.250$, so that the bond price goes down to $94.213 - 0.250 = 93.963$. How accurate is this? Valuing the bond in terms of its yield in the usual way, we find that, when the bond yield increases by 10 basis points to 12.1%, the bond price is

$$5e^{-0.121\times0.5} + 5e^{-0.121\times1.0} + 5e^{-0.121\times1.5} + 5e^{-0.121\times2.0} + 5e^{-0.121\times2.5} + 105e^{-0.121\times3.0} = 93.963$$

which is (to three decimal places) the same as that predicted by the duration relationship.

Modified Duration

The preceding analysis is based on the assumption that y is expressed with continuous compounding. If y is expressed with annual compounding, it can be shown that the approximate relationship in Equation (7.15) becomes

$$\Delta B = -\frac{BD\Delta y}{1+y}$$

More generally, if y is expressed with a compounding frequency of m times per year, then

$$\Delta B = -\frac{BD\Delta y}{1+y/m}$$

A variable D^*, defined by

$$D^* = \frac{D}{1+y/m}$$

is sometimes referred to as the bond's *modified duration*. It allows the duration relationship to be simplified to

$$\Delta B = -BD^*\Delta y \qquad (7.17)$$

when y is expressed with a compounding frequency of m times per year. The following example investigates the accuracy of the modified duration relationship.

Example 7.6

The bond in Table 7-6 has a price of 94.213 and a duration of 2.653. The yield, expressed with semiannual compounding is 12.3673%. The modified duration, D^*, is given by

$$D^* = \frac{2.653}{1+0.123673/2} = 2.499$$

From Equation (7.17),

$$\Delta B = -94.213 \times 2.4985 \times \Delta y$$

or

$$\Delta B = -235.39 \times \Delta y$$

When the yield (semiannually compounded) increases by 10 basis points (= 0.1%), we have $\Delta y = +0.001$. The duration relationship predicts that we expect ΔB to be $-235.39 \times 0.001 = -0.235$, so that the bond price goes down to $94.213 - 0.235 = 93.978$. How accurate is this? An exact calculation similar to that in the previous example shows that, when the bond yield (semiannually compounded) increases by 10 basis points to 12.4673%, the

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bond price becomes 93.978. This shows that the modified duration calculation gives good accuracy for small yield changes.

Another term that is sometimes used is *dollar duration*. This is the product of modified duration and bond price, so that $\Delta B = -D_{\$}\Delta y$, where $D_{\$}$ is dollar duration.

Bond Portfolios

The duration, D, of a bond portfolio can be defined as a weighted average of the durations of the individual bonds in the portfolio, with the weights being proportional to the bond prices. Equations (7.15) to (7.17) then apply, with B being defined as the value of the bond portfolio. They estimate the change in the value of the bond portfolio for a small change Δy in the yields of all the bonds.

It is important to realize that, when duration is used for bond portfolios, there is an implicit assumption that the yields of all bonds will change by approximately the same amount. When the bonds have widely differing maturities, this happens only when there is a parallel shift in the zero-coupon yield curve. We should therefore interpret Equations (7.15) to (7.17) as providing estimates of the impact on the price of a bond portfolio of a small parallel shift, Δy, in the zero curve.

By choosing a portfolio so that the duration of assets equals the duration of liabilities (i.e., the net duration is zero), a financial institution eliminates its exposure to small parallel shifts in the yield curve. But it is still exposed to shifts that are either large or nonparallel.

CONVEXITY

The duration relationship applies only to small changes in yields. This is illustrated in Figure 7-2, which shows the relationship between the percentage change in value and change in yield for two bond portfolios having the same duration. The gradients of the two curves are the same at the origin. This means that both bond portfolios change in value by the same percentage for small yield changes and is consistent with Equation (7.16). For large yield changes, the portfolios behave differently. Portfolio X has more curvature in its relationship with yields than portfolio Y. A factor known as *convexity* measures this

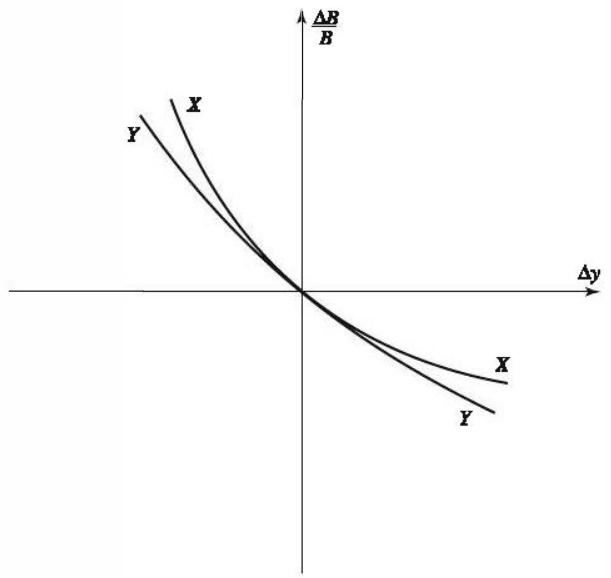

FIGURE 7-2 Two bond portfolios with the same duration.

curvature and can be used to improve the relationship in Equation (7.16).

A measure of convexity is

$$C = \frac{1}{B}\frac{d^2B}{dy^2} = \frac{\sum_{i=1}^{n} c_i t_i^2 e^{-yt_i}}{B}$$

From Taylor series expansions, we obtain a more accurate expression than Equation (7.13), given by

$$\Delta B = \frac{dB}{dy}\Delta y + \frac{1}{2}\frac{d^2B}{dy^2}\Delta y^2 \qquad (7.18)$$

This leads to

$$\frac{\Delta B}{B} = -D\Delta y + \frac{1}{2}C(\Delta y)^2$$

For a portfolio with a particular duration, the convexity of a bond portfolio tends to be greatest when the portfolio provides payments evenly over a long period of time. It is least when the payments are concentrated around one particular point in time. By choosing a portfolio of assets and liabilities with a net duration of zero and a net convexity of zero, a financial institution can make itself immune to relatively large parallel shifts in the zero curve. However, it is still exposed to nonparallel shifts.

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THEORIES OF THE TERM STRUCTURE OF INTEREST RATES

It is natural to ask what determines the shape of the zero curve. Why is it sometimes downward sloping, sometimes upward sloping, and sometimes partly upward sloping and partly downward sloping? A number of different theories have been proposed. The simplest is *expectations theory*, which conjectures that long-term interest rates should reflect expected future short-term interest rates. More precisely, it argues that a forward interest rate corresponding to a certain future period is equal to the expected future zero interest rate for that period. Another idea, *market segmentation theory*, conjectures that there need be no relationship between short-, medium-, and long-term interest rates. Under the theory, a major investor such as a large pension fund or an insurance company invests in bonds of a certain maturity and does not readily switch from one maturity to another. The short-term interest rate is determined by supply and demand in the short-term bond market; the medium-term interest rate is determined by supply and demand in the medium-term bond market; and so on.

The theory that is most appealing is *liquidity preference theory*. The basic assumption underlying the theory is that investors prefer to preserve their liquidity and invest funds for short periods of time. Borrowers, on the other hand, usually prefer to borrow at fixed rates for long periods of time. This leads to a situation in which forward rates are greater than expected future zero rates. The theory is also consistent with the empirical result that yield curves tend to be upward sloping more often than they are downward sloping.

The Management of Net Interest Income

To understand liquidity preference theory, it is useful to consider the interest rate risk faced by banks when they take deposits and make loans. The *net interest income* of the bank is the excess of the interest received over the interest paid and needs to be carefully managed.

Consider a simple situation where a bank offers consumers a one-year and a five-year deposit rate as well as a one-year and five-year mortgage rate. The rates are shown in Table 7-7. We make the simplifying assumption that the expected one-year interest rate for future time periods to equal the one-year rates prevailing in the market today. Loosely speaking this means that the market considers interest rate increases to be just as likely as interest rate decreases. As a result, the rates in Table 7-7 are "fair" in that they reflect the market's expectations (i.e., they correspond to expectations theory). Investing money for one year and reinvesting for four further one-year periods give the same expected overall return as a single five-year investment. Similarly, borrowing money for one year and refinancing each year for the next four years leads to the same expected financing costs as a single five-year loan.

TABLE 7-7 Example of Rates Offered by a Bank to Its Customers

Maturity (years)	Deposit Rate	Mortgage Rate
1	3%	6%
5	3%	6%

Suppose you have money to deposit and agree with the prevailing view that interest rate increases are just as likely as interest rate decreases. Would you choose to deposit your money for one year at 3% per annum or for five years at 3% per annum? The chances are that you would choose one year because this gives you more financial flexibility. It ties up your funds for a shorter period of time.

Now suppose that you want a mortgage. Again you agree with the prevailing view that interest rate increases are just as likely as interest rate decreases. Would you choose a one-year mortgage at 6% or a five-year mortgage at 6%? The chances are that you would choose a five-year mortgage because it fixes your borrowing rate for the next five years and subjects you to less refinancing risk.

When the bank posts the rates shown in Table 7-7, it is likely to find that the majority of its depositors opt for one-year deposits and the majority of its borrowers opt for five-year mortgages. This creates an asset/liability mismatch for the bank and subjects it to risks. There is no problem if interest rates fall. The bank will find itself financing the five-year 6% loans with deposits that cost less than 3% in the future and net interest income will increase. However, if rates rise, the deposits that are financing these 6% loans will cost more than 3% in the future and net interest income will decline. A 3% rise in interest rates would reduce the net interest income to zero.

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TABLE 7-8 Five-Year Rates Are Increased in an Attempt to Match Maturities of Assets and Liabilities

Maturity (years)	Deposit Rate	Mortgage Rate
1	3%	6%
5	4%	7%

It is the job of the asset/liability management group to ensure that the maturities of the assets on which interest is earned and the maturities of the liabilities on which interest is paid are matched. One way it can do this is by increasing the five-year rate on both deposits and mortgages. For example, it could move to the situation in Table 7-8 where the five-year deposit rate is 4% and the five-year mortgage rate 7%. This would make five-year deposits relatively more attractive and one-year mortgages relatively more attractive. Some customers who chose one-year deposits when the rates were as in Table 7-7 will switch to five-year deposits in the Table 7-8 situation. Some customers who chose five-year mortgages when the rates were as in Table 7-7 will choose one-year mortgages. This may lead to the maturities of assets and liabilities being matched. If there is still an imbalance with depositors tending to choose a one-year maturity and borrowers a five-year maturity, five-year deposit and mortgage rates could be increased even further. Eventually the imbalance will disappear.

The net result of all banks behaving in the way we have just described is liquidity preference theory. Long-term rates tend to be higher than those that would be predicted by expected future short-term rates. The yield curve is upward sloping most of the time. It is downward sloping only when the market expects a steep decline in short-term rates.

Many banks now have sophisticated systems for monitoring the decisions being made by customers so that, when they detect small differences between the maturities of the assets and liabilities being chosen by customers they can fine tune the rates they offer. Sometimes derivatives such as interest rate swaps (which will be discussed in Chapter 10) are also used to manage their exposure. The result of all this is that net interest income is usually very stable. This has not always been the case. In the United States, the failure of Savings and Loan companies in the 1980s and the failure of Continental Illinois in 1984 were to a large extent a result of the fact that they did not match the maturities of assets and liabilities. Both failures proved to be very expensive for US taxpayers.

Liquidity

In addition to creating problems in the way that has been described, a portfolio where maturities are mismatched can lead to liquidity problems. Consider a financial institution that funds 5-year fixed rate loans with wholesale deposits that last only 3 months. It might recognize its exposure to rising interest rates and hedge its interest rate risk. (One way of doing this is by using interest rate swaps, as mentioned earlier.) However, it still has a liquidity risk. Wholesale depositors may, for some reason, lose confidence in the financial institution and refuse to continue to provide the financial institution with short-term funding. The financial institution, even if it has adequate equity capital, will then experience a severe liquidity problem that could lead to its downfall. As described in Box 7-2, these types of liquidity problems were the root cause of some of the failures of financial institutions during the crisis that started in 2007.

BOX 7-2 Liquidity and the 2007–2009 Financial Crisis

During the credit crisis that started in July 2007 there was a "flight to quality," where financial institutions and investors looked for safe investments and were less inclined than before to take credit risks. Financial institutions that relied on short-term funding experienced liquidity problems. One example is Northern Rock in the United Kingdom, which chose to finance much of its mortgage portfolio with wholesale deposits, some lasting only 3 months. Starting in September 2007, the depositors became nervous and refused to roll over the funding they were providing to Northern Rock, i.e., at the end of a 3-month period they would refuse to deposit their funds for a further 3-month period. As a result, Northern Rock was unable to finance its assets. It was taken over by the UK government in early 2008. In the US, financial institutions such as Bear Stearns and Lehman Brothers experienced similar liquidity problems because they had chosen to fund part of their operations with short-term funds.

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SUMMARY

Two important interest rates for derivative traders are Treasury rates and LIBOR rates. Treasury rates are the rates paid by a government on borrowings in its own currency. LIBOR rates are short-term lending rates offered by banks in the interbank market.

The compounding frequency used for an interest rate defines the units in which it is measured. The difference between an annually compounded rate and a quarterly compounded rate is analogous to the difference between a distance measured in miles and a distance measured in kilometers. Traders frequently use continuous compounding when analyzing the value of options and more complex derivatives.

Many different types of interest rates are quoted in financial markets and calculated by analysts. The n-year zero or spot rate is the rate applicable to an investment lasting for n years when all of the return is realized at the end. The par yield on a bond of a certain maturity is the coupon rate that causes the bond to sell for its par value. Forward rates are the rates applicable to future periods of time implied by today's zero rates.

The method most commonly used to calculate zero rates is known as the bootstrap method. It involves starting with short-term instruments and moving progressively to longer-term instruments, making sure that the zero rates calculated at each stage are consistent with the prices of the instruments. It is used daily by trading desks to calculate a Treasury zero-rate curve.

A forward rate agreement (FRA) is an over-the-counter agreement that an interest rate (usually LIBOR) will be exchanged for a specified interest rate during a specified future period of time. An FRA can be valued by assuming that forward rates are realized and discounting the resulting payoff.

An important concept in interest rate markets is *duration*. Duration measures the sensitivity of the value of a bond portfolio to a small parallel shift in the zero-coupon yield curve. Specifically,

$$\Delta B = -BD\Delta y$$

where B is the value of the bond portfolio, D is the duration of the portfolio, Δy is the size of a small parallel shift in the zero curve, and ΔB is the resultant effect on the value of the bond portfolio.

Liquidity preference theory can be used to explain the interest rate term structures that are observed in practice. The theory argues that most entities like to borrow long and lend short. To match the maturities of borrowers and lenders, it is necessary for financial institutions to raise long-term rates so that forward interest rates are higher than expected future spot interest rates.

Further Reading

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Determination of Forward and Futures Prices

8

Learning Objectives

After completing this reading you should be able to:

- Differentiate between investment and consumption assets.
- Define short-selling and calculate the net profit of a short sale of a dividend-paying stock.
- Describe the differences between forward and futures contracts, and explain the relationship between forward and spot prices.
- Calculate the forward price given the underlying asset's spot price, and describe an arbitrage argument between spot and forward prices.
- Explain the relationship between forward and futures prices.
- Calculate a forward foreign exchange rate using the interest rate parity relationship.
- Define income, storage costs, and convenience yield.
- Calculate the futures price on commodities incorporating income/storage costs and/or convenience yields.
- Calculate, using the cost-of-carry model, forward prices where the underlying asset either does or does not have interim cash flows.
- Describe the various delivery options available in the futures markets and how they can influence futures prices.
- Explain the relationship between current futures prices and expected future spot prices, including the impact of systematic and nonsystematic risk.
- Define and interpret contango and backwardation, and explain how they relate to the cost-of-carry model.

Excerpt is Chapter 5 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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In this chapter we examine how forward prices and futures prices are related to the spot price of the underlying asset. Forward contracts are easier to analyze than futures contracts because there is no daily settlement—only a single payment at maturity. We therefore start this chapter by considering the relationship between the forward price and the spot price. Luckily it can be shown that the forward price and futures price of an asset are usually very close when the maturities of the two contracts are the same. This is convenient because it means that results obtained for forwards are usually also true for futures.

In the first part of the chapter we derive some important general results on the relationship between forward (or futures) prices and spot prices. We then use the results to examine the relationship between futures prices and spot prices for contracts on stock indices, foreign exchange, and commodities. We will consider interest rate futures contracts in the next chapter.

INVESTMENT ASSETS VS. CONSUMPTION ASSETS

When considering forward and futures contracts, it is important to distinguish between investment assets and consumption assets. An *investment asset* is an asset that is held for investment purposes by at least some traders. Stocks and bonds are clearly investment assets. Gold and silver are also examples of investment assets. Note that investment assets do not have to be held exclusively for investment. (Silver, for example, has a number of industrial uses.) However, they do have to satisfy the requirement that they are held by some traders solely for investment. A *consumption asset* is an asset that is held primarily for consumption. It is not normally held for investment. Examples of consumption assets are commodities such as copper, crude oil, corn, and pork bellies.

As we shall see later in this chapter, we can use arbitrage arguments to determine the forward and futures prices of an investment asset from its spot price and other observable market variables. We cannot do this for consumption assets.

SHORT SELLING

Some of the arbitrage strategies presented in this chapter involve *short selling*. This trade, usually simply referred to as "shorting," involves selling an asset that is not owned. It is something that is possible for some—but not all—investment assets. We will illustrate how it works by considering a short sale of shares of a stock.

Suppose an investor instructs a broker to short 500 shares of company X. The broker will carry out the instructions by borrowing the shares from someone who owns them and selling them in the market in the usual way. At some later stage, the investor will close out the position by purchasing 500 shares of company X in the market. These shares are then used to replace the borrowed shares so that the short position is closed out. The investor takes a profit if the stock price has declined and a loss if it has risen. If at any time while the contract is open the broker has to return the borrowed shares and there are no other shares that can be borrowed, the investor is forced to close out the position, even if not ready to do so. Sometimes a fee is charged for lending the shares to the party doing the shorting.

An investor with a short position must pay to the broker any income, such as dividends or interest, that would normally be received on the securities that have been shorted. The broker will transfer this income to the account of the client from whom the securities have been borrowed. Consider the position of an investor who shorts 500 shares in April when the price per share is \$120 and closes out the position by buying them back in July when the price per share is \$100. Suppose that a dividend of \$1 per share is paid in May. The investor receives 500 × \$120 = \$60,000 in April when the short position is initiated. The dividend leads to a payment by the investor of 500 × \$1 = \$500 in May. The investor also pays 500 × \$100 = \$50,000 for shares when the position is closed out in July. The net gain, therefore, is

$$\$60{,}000 - \$500 - \$50{,}000 = \$9{,}500$$

assuming there is no fee for borrowing the shares. Table 8-1 illustrates this example and shows that the cash flows from the short sale are the mirror image of the cash flows from purchasing the shares in April and selling them in July. (Again, this assumes no borrowing fee.)

The investor is required to maintain a margin account with the broker. The margin account consists of cash or marketable securities deposited by the investor with the broker to guarantee that the investor will not walk away from the short position if the share price increases. It is similar to the margin account discussed in Chapter 5 for futures contracts. An initial margin is required and if there are adverse movements (i.e., increases) in the price

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TABLE 8-1 Cash Flows from Short Sale and Purchase of Shares

Purchase of Shares	
April: Purchase 500 shares for $120	−$60,000
May: Receive dividend	+$500
July: Sell 500 shares for $100 per share	+$50,000
	Net profit = −$9,500
Short Sale of Shares	
April: Borrow 500 shares and sell them for $120	+$60,000
May: Pay dividend	−$500
July: Buy 500 shares for $100 per share Replace borrowed shares to close short position	−$50,000
	Net profit = +$9,500

of the asset that is being shorted, additional margin may be required. If the additional margin is not provided, the short position is closed out. The margin account does not represent a cost to the investor. This is because interest is usually paid on the balance in margin accounts and, if the interest rate offered is unacceptable, marketable securities such as Treasury bills can be used to meet margin requirements. The proceeds of the sale of the asset belong to the investor and normally form part of the initial margin.

From time to time regulations are changed on short selling. In 1938, the uptick rule was introduced. This allowed shares to be shorted only on an "uptick"—that is, when the most recent movement in the share price was an increase. The SEC abolished the uptick rule in July 2007, but introduced an "alternative uptick" rule in February 2010. Under this rule, when the price of a stock has decreased by more than 10% in one day, there are restrictions on short selling for that day and the next. These restrictions are that the stock can be shorted only at a price that is higher than the best current bid price. Occasionally there are temporary bans on short selling. This happened in a number of countries in 2008 because it was considered that short selling contributed to the high market volatility that was being experienced.

ASSUMPTIONS AND NOTATION

In this chapter we will assume that the following are all true for some market participants:

1. The market participants are subject to no transaction costs when they trade.
2. The market participants are subject to the same tax rate on all net trading profits.
3. The market participants can borrow money at the same risk-free rate of interest as they can lend money.
4. The market participants take advantage of arbitrage opportunities as they occur.

Note that we do not require these assumptions to be true for all market participants. All that we require is that they be true—or at least approximately true—for a few key market participants such as large derivatives dealers. It is the trading activities of these key market participants and their eagerness to take advantage of arbitrage opportunities as they occur that determine the relationship between forward and spot prices.

The following notation will be used throughout this chapter:

T: Time until delivery date in a forward or futures contract (in years)

S_0: Price of the asset underlying the forward or futures contract today

F_0: Forward or futures price today

r: Zero-coupon risk-free rate of interest per annum, expressed with continuous compounding, for an investment maturing at the delivery date (i.e., in T years).

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The risk-free rate, r, is the rate at which money is borrowed or lent when there is no credit risk, so that the money is certain to be repaid. As discussed in Chapter 7, participants in derivatives markets have traditionally used LIBOR as a proxy for the risk-free rate, but events during the crisis have led them to switch to other alternatives in some instances.

FORWARD PRICE FOR AN INVESTMENT ASSET

The easiest forward contract to value is one written on an investment asset that provides the holder with no income. Non-dividend-paying stocks and zero-coupon bonds are examples of such investment assets.

Consider a long forward contract to purchase a non-dividend-paying stock in 3 months.[1] Assume the current stock price is \$40 and the 3-month risk-free interest rate is 5% per annum.

Suppose first that the forward price is relatively high at \$43. An arbitrageur can borrow \$40 at the risk-free interest rate of 5% per annum, buy one share, and short a forward contract to sell one share in 3 months. At the end of the 3 months, the arbitrageur delivers the share and receives \$43. The sum of money required to pay off the loan is

$$40e^{0.05\times3/12} = \$40.50$$

By following this strategy, the arbitrageur locks in a profit of \$43.00 − \$40.50 = \$2.50 at the end of the 3-month period.

Suppose next that the forward price is relatively low at \$39. An arbitrageur can short one share, invest the proceeds of the short sale at 5% per annum for 3 months, and take a long position in a 3-month forward contract. The proceeds of the short sale grow to $40e^{0.05\times3/12}$ or \$40.50 in 3 months. At the end of the 3 months, the arbitrageur pays \$39, takes delivery of the share under the terms of the forward contract, and uses it to close out the short position. A net gain of

$$\$40.50 - \$39.00 = \$1.50$$

is therefore made at the end of the 3 months. The two trading strategies we have considered are summarized in Table 8-2.

Under what circumstances do arbitrage opportunities such as those in Table 8-2 not exist? The first arbitrage works when the forward price is greater than \$40.50. The second arbitrage works when the forward price is less than \$40.50. We deduce that for there to be no arbitrage the forward price must be exactly \$40.50.

A Generalization

To generalize this example, we consider a forward contract on an investment asset with price S_0 that provides no income. Using our notation, T is the time to maturity, r is the risk-free rate, and F_0 is the forward price. The relationship between F_0 and S_0 is

$$F_0 = S_0e^{rT} \tag{8.1}$$

If $F_0 > S_0e^{rT}$, arbitrageurs can buy the asset and short forward contracts on the asset. If $F_0 < S_0e^{rT}$, they can short the asset and enter into long forward contracts on it.[2] In our example, $S_0 = 40$, $r = 0.05$, and $T = 0.25$, so that Equation (8.1) gives

$$F_0 = 40e^{0.05\times0.25} = \$40.50$$

which is in agreement with our earlier calculations.

A long forward contract and a spot purchase both lead to the asset being owned at time T. The forward price is higher than the spot price because of the cost of financing the spot purchase of the asset during the life of the forward contract. This point was overlooked by Kidder Peabody in 1994, much to its cost (see Box 8-1).

Example 8.1

Consider a 4-month forward contract to buy a zero-coupon bond that will mature 1 year from today. (This means that the bond will have 8 months to go when the forward contract matures.) The current price of the bond is \$930. We assume that the 4-month risk-free rate of interest (continuously compounded) is 6% per annum.

[1] Forward contracts on individual stocks do not often arise in practice. However, they form useful examples for developing our ideas. Futures on individual stocks started trading in the United States in November 2002.

[2] For another way of seeing that Equation (8.1) is correct, consider the following strategy: buy one unit of the asset and enter into a short forward contract to sell it for F_0 at time T. This costs S_0 and is certain to lead to a cash inflow of F_0 at time T. Therefore S_0 must equal the present value of F_0; that is, $S_0 = F_0e^{-rT}$, or equivalently $F_0 = S_0e^{rT}$.

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TABLE 8-2 Arbitrage Opportunities When Forward Price Is Out of Line with Spot Price for Asset Providing No Income (Asset price = $40; interest rate = 5%; maturity of forward contract = 3 months)

Forward Price = $43	**Forward Price = $39**
Action now:	*Action now:*
Borrow $40 at 5% for 3 months Buy one unit of asset Enter into forward contract to sell asset in 3 months for $43	Short 1 unit of asset to realize $40 Invest $40 at 5% for 3 months Enter into a forward contract to buy asset in 3 months for $39
Action in 3 months:	*Action in 3 months:*
Sell asset for $43 Use $40.50 to repay loan with interest	Buy asset for $39 Close short position Receive $40.50 from investment
Profit realized = $2.50	Profit realized = $1.50

BOX 8-1 Kidder Peabody's Embarrassing Mistake

Investment banks have developed a way of creating a zero-coupon bond, called a *strip*, from a coupon-bearing Treasury bond by selling each of the cash flows underlying the coupon-bearing bond as a separate security. Joseph Jett, a trader working for Kidder Peabody, had a relatively simple trading strategy. He would buy strips and sell them in the forward market. As Equation (8.1) shows, the forward price of a security providing no income is always higher than the spot price. Suppose, for example, that the 3-month interest rate is 4% per annum and the spot price of a strip is $70. The 3-month forward price of the strip is $70e^{0.04\times3/12} = \$70.70$.

Kidder Peabody's computer system reported a profit on each of Jett's trades equal to the excess of the forward price over the spot price ($0.70 in our example). In fact, this profit was nothing more than the cost of financing the purchase of the strip. But, by rolling his contracts forward, Jett was able to prevent this cost from accruing to him.

The result was that the system reported a profit of $100 million on Jett's trading (and Jett received a big bonus) when in fact there was a loss in the region of $350 million. This shows that even large financial institutions can get relatively simple things wrong!

Because zero-coupon bonds provide no income, we can use Equation (8.1) with $T = 4/12$, $r = 0.06$, and $S_0 = 930$. The forward price, F_0, is given by

$$F_0 = 930e^{0.06\times4/12} = \$948.79$$

This would be the delivery price in a contract negotiated today.

What If Short Sales Are Not Possible?

Short sales are not possible for all investment assets and sometimes a fee is charged for borrowing assets. As it happens, this does not matter. To derive Equation (8.1), we do not need to be able to short the asset. All that we require is that there be market participants who hold the asset purely for investment (and by definition this is always true of an investment asset). If the forward price is too low, they will find it attractive to sell the asset and take a long position in a forward contract.

Suppose that the underlying investment asset gives rise to no storage costs or income. If $F_0 > S_0e^{rT}$, an investor can adopt the following strategy:

1. Borrow S_0 dollars at an interest rate r for T years.
2. Buy 1 unit of the asset.
3. Short a forward contract on 1 unit of the asset.

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At time T, the asset is sold for F_0. An amount S_0e^{rT} is required to repay the loan at this time and the investor makes a profit of $F_0 - S_0e^{rT}$.

Suppose next that $F_0 < S_0e^{rT}$. In this case, an investor who owns the asset can:

1. Sell the asset for S_0.
2. Invest the proceeds at interest rate r for time T.
3. Take a long position in a forward contract on 1 unit of the asset.

At time T, the cash invested has grown to S_0e^{rT}. The asset is repurchased for F_0 and the investor makes a profit of $S_0e^{rT} - F_0$ relative to the position the investor would have been in if the asset had been kept.

As in the non-dividend-paying stock example considered earlier, we can expect the forward price to adjust so that neither of the two arbitrage opportunities we have considered exists. This means that the relationship in Equation (8.1) must hold.

KNOWN INCOME

In this section we consider a forward contract on an investment asset that will provide a perfectly predictable cash income to the holder. Examples are stocks paying known dividends and coupon-bearing bonds. We adopt the same approach as in the previous section. We first look at a numerical example and then review the formal arguments.

Consider a long forward contract to purchase a coupon-bearing bond whose current price is \$900. We will suppose that the forward contract matures in 9 months. We will also suppose that a coupon payment of \$40 is expected after 4 months. We assume that the 4-month and 9-month risk-free interest rates (continuously compounded) are, respectively, 3% and 4% per annum.

Suppose first that the forward price is relatively high at \$910. An arbitrageur can borrow \$900 to buy the bond and short a forward contract. The coupon payment has a present value of $40e^{-0.03\times4/12} = \$39.60$. Of the \$900, \$39.60 is therefore borrowed at 3% per annum for 4 months so that it can be repaid with the coupon payment. The remaining \$860.40 is borrowed at 4% per annum for 9 months. The amount owing at the end of the 9-month period is $860.40e^{0.04\times0.75} = \$886.60$. A sum of \$910 is received for the bond under the terms of the forward contract. The arbitrageur therefore makes a net profit of

$$910.00 - 886.60 = \$23.40$$

Suppose next that the forward price is relatively low at \$870. An investor can short the bond and enter into a long forward contract. Of the \$900 realized from shorting the bond, \$39.60 is invested for 4 months at 3% per annum so that it grows into an amount sufficient to pay the coupon on the bond. The remaining \$860.40 is invested for 9 months at 4% per annum and grows to \$886.60. Under the terms of the forward contract, \$870 is paid to buy the bond and the short position is closed out. The investor therefore gains

$$886.60 - 870 = \$16.60$$

The two strategies we have considered are summarized in Table 8-3.[3] The first strategy in Table 8-3 produces a profit when the forward price is greater than \$886.60, whereas the second strategy produces a profit when the forward price is less than \$886.60. It follows that if there are no arbitrage opportunities then the forward price must be \$886.60.

A Generalization

We can generalize from this example to argue that, when an investment asset will provide income with a present value of I during the life of a forward contract, we have

$$F_0 = (S_0 - I)e^{rT} \tag{8.2}$$

In our example, $S_0 = 900.00$, $I = 40e^{-0.03\times4/12} = 39.60$, $r = 0.04$, and $T = 0.75$, so that

$$F_0 = (900.00 - 39.60)e^{0.04\times0.75} = \$886.60$$

This is in agreement with our earlier calculation. Equation (8.2) applies to any investment asset that provides a known cash income.

If $F_0 > (S_0 - I)e^{rT}$, an arbitrageur can lock in a profit by buying the asset and shorting a forward contract on the asset; if $F_0 < (S_0 - I)e^{rT}$, an arbitrageur can lock in a profit by shorting the asset and taking a long position in a forward contract. If short sales are not possible, investors

[3] If shorting the bond is not possible, investors who already own the bond will sell it and buy a forward contract on the bond increasing the value of their position by \$16.60. This is similar to the strategy we described for the asset in the previous section.

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TABLE 8-3 Arbitrage Opportunities When 9-Month Forward Price Is Out of Line with Spot Price for Asset Providing Known Cash Income (Asset price = $900; income of $40 occurs at 4 months; 4-month and 9-month rates are, respectively, 3% and 4% per annum)

Forward Price = $910	**Forward Price = $870**
Action now:	*Action now*:
Borrow $900: $39.60 for 4 months and $860.40 for 9 months Buy 1 unit of asset Enter into forward contract to sell asset in 9 months for $910	Short 1 unit of asset to realize $900 Invest $39.60 for 4 months and $860.40 for 9 months Enter into a forward contract to buy asset in 9 months for $870
Action in 4 months:	*Action in 4 months*:
Receive $40 of income on asset Use $40 to repay first loan with interest	Receive $40 from 4-month investment Pay income of $40 on asset
Action in 9 months:	*Action in 9 months*:
Sell asset for $910 Use $886.60 to repay second loan with interest	Receive $886.60 from 9-month investment Buy asset for $870 Close out short position
Profit realized = $23.40	Profit realized = $16.60

who own the asset will find it profitable to sell the asset and enter into long forward contracts.[4]

Example 8.2

Consider a 10-month forward contract on a stock when the stock price is $50. We assume that the risk-free rate of interest (continuously compounded) is 8% per annum for all maturities. We also assume that dividends of $0.75 per share are expected after 3 months, 6 months, and 9 months. The present value of the dividends, I, is

$$I = 0.75e^{-0.08\times3/12} + 0.75e^{-0.08\times6/12} + 0.75e^{-0.08\times9/12} = 2.162$$

The variable T is 10 months, so that the forward price, F_0, from Equation (8.2), is given by

$$F_0 = (50 - 2.162)e^{-0.08\times10/12} = \$51.14$$

[4] For another way of seeing that Equation (8.2) is correct, consider the following strategy: buy one unit of the asset and enter into a short forward contract to sell it for F_0 at time T. This costs S_0 and is certain to lead to a cash inflow of F_0 at time T and an income with a present value of I. The initial outflow is S_0. The present value of the inflows is $I + F_0e^{-rT}$. Hence, $S_0 = I + F_0e^{-rT}$, or equivalently $F_0 = (S_0 - I)e^{rT}$.

If the forward price were less than this, an arbitrageur would short the stock and buy forward contracts. If the forward price were greater than this, an arbitrageur would short forward contracts and buy the stock in the spot market.

KNOWN YIELD

We now consider the situation where the asset underlying a forward contract provides a known yield rather than a known cash income. This means that the income is known when expressed as a percentage of the asset's price at the time the income is paid. Suppose that an asset is expected to provide a yield of 5% per annum. This could mean that income is paid once a year and is equal to 5% of the asset price at the time it is paid, in which case the yield would be 5% with annual compounding. Alternatively, it could mean that income is paid twice a year and is equal to 2.5% of the asset price at the time it is paid, in which case the yield would be 5% per annum with semi-annual compounding. In Chapter 7 we explained that we

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will normally measure interest rates with continuous compounding. Similarly, we will normally measure yields with continuous compounding. Formulas for translating a yield measured with one compounding frequency to a yield measured with another compounding frequency are the same as those given for interest rates in Chapter 7.

Define q as the average yield per annum on an asset during the life of a forward contract with continuous compounding. It can be shown that

$$F_0 = S_0 e^{(r-q)T} \tag{8.3}$$

Example 8.3

Consider a 6-month forward contract on an asset that is expected to provide income equal to 2% of the asset price once during a 6-month period. The risk-free rate of interest (with continuous compounding) is 10% per annum. The asset price is \$25. In this case, $S_0 = 25$, $r = 0.10$, and $T = 0.5$. The yield is 4% per annum with semiannual compounding. From Equation (7.3), this is 3.96% per annum with continuous compounding. It follows that $q = 0.0396$, so that from Equation (8.3) the forward price, F_0, is given by

$$F_0 = 25e^{(0.10-0.0396)\times 0.5} = \$25.77$$

VALUING FORWARD CONTRACTS

The value of a forward contract at the time it is first entered into is close to zero. At a later stage, it may prove to have a positive or negative value. It is important for banks and other financial institutions to value the contract each day. (This is referred to as marking to market the contract.) Using the notation introduced earlier, we suppose K is the delivery price for a contract that was negotiated some time ago, the delivery date is T years from today, and r is the T-year risk-free interest rate. The variable F_0 is the forward price that would be applicable if we negotiated the contract today. In addition, we define f to be the value of forward contract today.

It is important to be clear about the meaning of the variables F_0, K, and f. At the beginning of the life of the forward contract, the delivery price, K, is set equal to the forward price at that time and the value of the contract, f, is 0. As time passes, K stays the same (because it is part of the definition of the contract), but the forward price changes and the value of the contract becomes either positive or negative.

A general result, applicable to all long forward contracts (both those on investment assets and those on consumption assets), is

$$f = (F_0 - K)e^{-rT} \tag{8.4}$$

To see why Equation (8.4) is correct, we use an argument analogous to the one we used for forward rate agreements in Chapter 7. We form a portfolio today consisting of (a) a forward contract to buy the underlying asset for K at time T and (b) a forward contract to sell the asset for F_0 at time T. The payoff from the portfolio at time T is $S_T - K$ from the first contract and $F_0 - S_T$ from the second contract. The total payoff is $F_0 - K$ and is known for certain today. The portfolio is therefore a risk-free investment and its value today is the payoff at time T discounted at the risk-free rate or $(F_0 - K)e^{-rT}$. The value of the forward contract to sell the asset for F_0 is worth zero because F_0 is the forward price that applies to a forward contract entered into today. It follows that the value of a (long) forward contract to buy an asset for K at time T must be $(F_0 - K)e^{-rT}$. Similarly, the value of a (short) forward contract to sell the asset for K at time T is $(K - F_0)e^{-rT}$.

Example 8.4

A long forward contract on a non-dividend-paying stock was entered into some time ago. It currently has 6 months to maturity. The risk-free rate of interest (with continuous compounding) is 10% per annum, the stock price is \$25, and the delivery price is \$24. In this case, $S_0 = 25$, $r = 0.10$, $T = 0.5$, and $K = 24$. From Equation (8.1), the 6-month forward price, F_0, is given by

$$F_0 = 25e^{0.1\times 0.5} = \$26.28$$

From Equation (8.4), the value of the forward contract is

$$f = (26.28 - 24)e^{-0.1\times 0.5} = \$2.17$$

Equation (8.4) shows that we can value a long forward contract on an asset by making the assumption that the price of the asset at the maturity of the forward contract equals the forward price F_0. To see this, note that when we make that assumption, a long forward contract provides a payoff at time T of $F_0 - K$. This has a present value of $(F_0 - K)e^{-rT}$, which is the value of f in Equation (8.4). Similarly, we can value a short forward contract on the asset by assuming that the current forward price of the asset is realized. These results are analogous to the result in Chapter 7 that we can value a forward rate agreement on the assumption that forward rates are realized.

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Using Equation (8.4) in conjunction with Equation (8.1) gives the following expression for the value of a forward contract on an investment asset that provides no income

$$f = S_0 - Ke^{-rT} \tag{8.5}$$

Similarly, using Equation (8.4) in conjunction with Equation (8.2) gives the following expression for the value of a long forward contract on an investment asset that provides a known income with present value I:

$$f = S_0 - I - Ke^{-rT} \tag{8.6}$$

Finally, using Equation (8.4) in conjunction with Equation (8.3) gives the following expression for the value of a long forward contract on an investment asset that provides a known yield at rate q:

$$f = S_0e^{-qT} - Ke^{-rT} \tag{8.7}$$

When a futures price changes, the gain or loss on a futures contract is calculated as the change in the futures price multiplied by the size of the position. This gain is realized almost immediately because futures contracts are settled daily. Equation (8.4) shows that, when a forward price changes, the gain or loss is the present value of the change in the forward price multiplied by the size of the position. The difference between the gain/loss on forward and futures contracts can cause confusion on a foreign exchange trading desk (see Box 8-2).

BOX 8-2 A Systems Error?

A foreign exchange trader working for a bank enters into a long forward contract to buy 1 million pounds sterling at an exchange rate of 1.5000 in 3 months. At the same time, another trader on the next desk takes a long position in 16 contracts for 3-month futures on sterling. The futures price is 1.5000 and each contract is on 62,500 pounds. The positions taken by the forward and futures traders are therefore the same. Within minutes of the positions being taken, the forward and the futures prices both increase to 1.5040. The bank's systems show that the futures trader has made a profit of $4,000, while the forward trader has made a profit of only $3,900. The forward trader immediately calls the bank's systems department to complain. Does the forward trader have a valid complaint?

The answer is no! The daily settlement of futures contracts ensures that the futures trader realizes an almost immediate profit corresponding to the increase in the futures price. If the forward trader closed out the position by entering into a short contract at 1.5040, the forward trader would have contracted to buy 1 million pounds at 1.5000 in 3 months and sell 1 million pounds at 1.5040 in 3 months. This would lead to a $4,000 profit—but in 3 months, not today. The forward trader's profit is the present value of $4,000. This is consistent with Equation (8.4).

The forward trader can gain some consolation from the fact that gains and losses are treated symmetrically. If the forward/futures prices dropped to 1.4960 instead of rising to 1.5040, then the futures trader would take a loss of $4,000 while the forward trader would take a loss of only $3,900.

ARE FORWARD PRICES AND FUTURES PRICES EQUAL?

Technical Note 24 at www.rotman.utoronto.ca/~hull/TechnicalNotes provides an arbitrage argument to show that, when the short-term risk-free interest rate is constant, the forward price for a contract with a certain delivery date is in theory the same as the futures price for a contract with that delivery date. The argument can be extended to cover situations where the interest rate is a known function of time.

When interest rates vary unpredictably (as they do in the real world), forward and futures prices are in theory no longer the same. We can get a sense of the nature of the relationship by considering the situation where the price of the underlying asset, S, is strongly positively correlated with interest rates. When S increases, an investor who holds a long futures position makes an immediate gain because of the daily settlement procedure. The positive correlation indicates that it is likely that interest rates have also increased. The gain will therefore tend to be invested at a higher than average rate of interest. Similarly, when S decreases, the investor will incur an immediate loss. This loss will tend to be financed at a lower than average rate of interest. An investor holding a forward contract rather than a futures contract is not affected in this way by interest rate movements. It follows that a long futures contract will be slightly more attractive than a similar long forward contract. Hence, when S is strongly positively correlated with interest rates, futures prices will tend to be slightly higher than forward prices. When S is strongly negatively correlated with interest rates, a similar argument shows that forward prices will tend to be slightly higher than futures prices.

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The theoretical differences between forward and futures prices for contracts that last only a few months are in most circumstances sufficiently small to be ignored. In practice, there are a number of factors not reflected in theoretical models that may cause forward and futures prices to be different. These include taxes, transactions costs, and margin requirements. The risk that the counterparty will default may be less in the case of a futures contract because of the role of the exchange clearing house. Also, in some instances, futures contracts are more liquid and easier to trade than forward contracts. Despite all these points, for most purposes it is reasonable to assume that forward and futures prices are the same. This is the assumption we will usually make in this book. We will use the symbol F_0 to represent both the futures price and the forward price of an asset today.

One exception to the rule that futures and forward contracts can be assumed to be the same concerns Eurodollar futures. This will be discussed in Chapter 9.

FUTURES PRICES OF STOCK INDICES

We introduced futures on stock indices in Chapter 6 and showed how a stock index futures contract is a useful tool in managing equity portfolios. Table 6-3 shows futures prices for a number of different indices. We are now in a position to consider how index futures prices are determined.

A stock index can usually be regarded as the price of an investment asset that pays dividends.[5] The investment asset is the portfolio of stocks underlying the index, and the dividends paid by the investment asset are the dividends that would be received by the holder of this portfolio. It is usually assumed that the dividends provide a known yield rather than a known cash income. If q is the dividend yield rate, Equation (8.3) gives the futures price, F_0, as

$$F_0 = S_0 e^{(r-q)T} \tag{8.8}$$

This shows that the futures price increases at rate $r - q$ with the maturity of the futures contract. In Table 6-3, the December futures settlement price of the S&P 500 is about 0.75% less than the June settlement price. This indicates that, on May 14, 2013, the short-term risk-free rate r was less than the dividend yield q by about 1.5% per year.

[5] Occasionally this is not the case: see Box 8-3.

BOX 8-3 The CME Nikkei 225 Futures Contract

The arguments in this chapter on how index futures prices are determined require that the index be the value of an investment asset. This means that it must be the value of a portfolio of assets that can be traded. The asset underlying the Chicago Mercantile Exchange's futures contract on the Nikkei 225 Index does not qualify, and the reason why is quite subtle. Suppose S is the value of the Nikkei 225 Index. This is the value of a portfolio of 225 Japanese stocks measured in yen. The variable underlying the CME futures contract on the Nikkei 225 has a *dollar value* of $5S$. In other words, the futures contract takes a variable that is measured in yen and treats it as though it is dollars.

We cannot invest in a portfolio whose value will always be $5S$ dollars. The best we can do is to invest in one that is always worth $5S$ yen or in one that is always worth $5QS$ dollars, where Q is the dollar value of 1 yen. The variable $5S$ dollars is not, therefore, the price of an investment asset and Equation (8.8) does not apply.

CME's Nikkei 225 futures contract is an example of a *quanto*. A quanto is a derivative where the underlying asset is measured in one currency and the payoff is in another currency.

Example 8.5

Consider a 3-month futures contract on an index. Suppose that the stocks underlying the index provide a dividend yield of 1% per annum, that the current value of the index is 1,300, and that the continuously compounded risk-free interest rate is 5% per annum. In this case, $r = 0.05$, $S_0 = 1{,}300$, $T = 0.25$, and $q = 0.01$. Hence, the futures price, F_0, is given by

$$F_0 = 1{,}300e^{(0.05-0.01)\times 0.25} = \$1{,}313.07$$

In practice, the dividend yield on the portfolio underlying an index varies week by week throughout the year. For example, a large proportion of the dividends on the NYSE stocks are paid in the first week of February, May, August, and November each year. The chosen value of q should represent the average annualized dividend yield during the life of the contract. The dividends used for estimating q should be those for which the ex-dividend date is during the life of the futures contract.

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Index Arbitrage

If $F_0 > S_0e^{(r-q)T}$, profits can be made by buying the stocks underlying the index at the spot price (i.e., for immediate delivery) and shorting futures contracts. If $F_0 < S_0e^{(r-q)T}$, profits can be made by doing the reverse—that is, shorting or selling the stocks underlying the index and taking a long position in futures contracts. These strategies are known as *index arbitrage*. When $F_0 < S_0e^{(r-q)T}$, index arbitrage is often done by a pension fund that owns an indexed portfolio of stocks. When $F_0 > S_0e^{(r-q)T}$, it might be done by a bank or a corporation holding short-term money market investments. For indices involving many stocks, index arbitrage is sometimes accomplished by trading a relatively small representative sample of stocks whose movements closely mirror those of the index. Usually index arbitrage is implemented through *program trading*. This involves using a computer system to generate the trades.

Most of the time the activities of arbitrageurs ensure that Equation (8.8) holds, but occasionally arbitrage is impossible and the futures price does get out of line with the spot price (see Box 8-4).

BOX 8-4 Index Arbitrage in October 1987

To do index arbitrage, a trader must be able to trade both the index futures contract and the portfolio of stocks underlying the index very quickly at the prices quoted in the market. In normal market conditions this is possible using program trading, and the relationship in Equation (8.8) holds well. Examples of days when the market was anything but normal are October 19 and 20 of 1987. On what is termed "Black Monday," October 19, 1987, the market fell by more than 20%, and the 604 million shares traded on the New York Stock Exchange easily exceeded all previous records. The exchange's systems were overloaded, and orders placed to buy or sell shares on that day could be delayed by up to two hours before being executed.

For most of October 19, 1987, futures prices were at a significant discount to the underlying index. For example, at the close of trading the S&P 500 Index was at 225.06 (down 57.88 on the day), whereas the futures price for December delivery on the S&P 500 was 201.50 (down 80.75 on the day). This was largely because the delays in processing orders made index arbitrage impossible. On the next day, Tuesday, October 20, 1987, the New York Stock Exchange placed temporary restrictions on the way in which program trading could be done. This also made index arbitrage very difficult and the breakdown of the traditional linkage between stock indices and stock index futures continued. At one point the futures price for the December contract was 18% less than the S&P 500 Index. However, after a few days the market returned to normal, and the activities of arbitrageurs ensured that Equation (8.8) governed the relationship between futures and spot prices of indices.

FORWARD AND FUTURES CONTRACTS ON CURRENCIES

We now move on to consider forward and futures foreign currency contracts from the perspective of a US investor. The underlying asset is one unit of the foreign currency. We will therefore define the variable S_0 as the current spot price in US dollars of one unit of the foreign currency and F_0 as the forward or futures price in US dollars of one unit of the foreign currency. This is consistent with the way we have defined S_0 and F_0 for other assets underlying forward and futures contracts. However, as mentioned in Chapter 5, it does not necessarily correspond to the way spot and forward exchange rates are quoted. For major exchange rates other than the British pound, euro, Australian dollar, and New Zealand dollar, a spot or forward exchange rate is normally quoted as the number of units of the currency that are equivalent to one US dollar.

A foreign currency has the property that the holder of the currency can earn interest at the risk-free interest rate prevailing in the foreign country. For example, the holder can invest the currency in a foreign-denominated bond. We define r_f as the value of the foreign risk-free interest rate when money is invested for time T. The variable r is the risk-free rate when money is invested for this period of time in US dollars.

The relationship between F_0 and S_0 is

$$F_0 = S_0e^{(r-r_f)T} \tag{8.9}$$

This is the well-known interest rate parity relationship from international finance. The reason it is true is illustrated in Figure 8-1. Suppose that an individual starts with 1,000 units of the foreign currency. There are two ways it can be converted to dollars at time T. One is by investing it for T years at r_f and entering into a forward contract to sell the proceeds for dollars at time T. This generates $1{,}000e^{r_fT}F_0$ dollars. The other is by exchanging the foreign currency for dollars in the spot market and investing the

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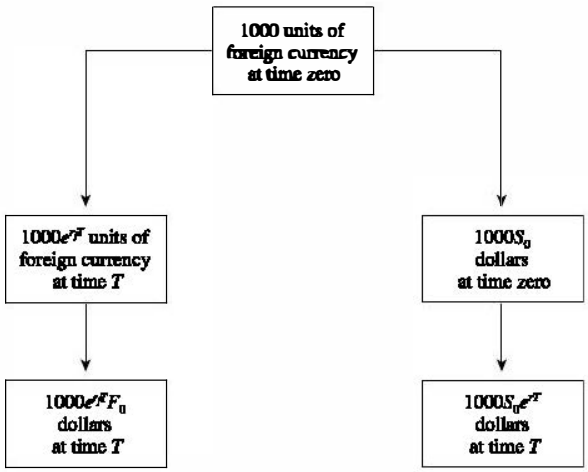

FIGURE 8-1 Two ways of converting 1,000 units of a foreign currency to dollars at time T. Here, S_0 is spot exchange rate, F_0 is forward exchange rate, and r and r_f are the dollar and foreign risk-free rates.

proceeds for T years at rate r. This generates $1{,}000S_0e^{rT}$ dollars. In the absence of arbitrage opportunities, the two strategies must give the same result. Hence,

$$1{,}000e^{r_fT}F_0 = 1{,}000S_0e^{rT}$$

so that

$$F_0 = S_0e^{(r-r_f)T}$$

Example 8.6

Suppose that the 2-year interest rates in Australia and the United States are 3% and 1%, respectively, and the spot exchange rate is 0.9800 USD per AUD. From Equation (8.9), the 2-year forward exchange rate should be

$$0.9800e^{(0.01-0.03)\times 2} = 0.9416$$

Suppose first that the 2-year forward exchange rate is less than this, say 0.9300. An arbitrageur can:

1. Borrow 1,000 AUD at 3% per annum for 2 years, convert to 980 USD and invest the USD at 1% (both rates are continuously compounded).
2. Enter into a forward contract to buy 1,061.84 AUD for 1,061.84 × 0.93 = 987.51 USD.

The 980 USD that are invested at 1% grow to $980e^{0.01\times 2} = 999.80$ USD in 2 years. Of this, 987.51 USD are used to purchase 1,061.84 AUD under the terms of the forward contract. This is exactly enough to repay principal and interest on the 1,000 AUD that are borrowed ($1{,}000e^{0.03\times 2} = 1{,}061.84$). The strategy therefore gives rise to a riskless profit of 999.80 − 987.51 = 12.29 USD. (If this does not sound very exciting, consider following a similar strategy where you borrow 100 million AUD!)

Suppose next that the 2-year forward rate is 0.9600 (greater than the 0.9416 value given by Equation (8.9)). An arbitrageur can:

1. Borrow 1,000 USD at 1% per annum for 2 years, convert to 1,000/0.9800 = 1,020.41 AUD, and invest the AUD at 3%.
2. Enter into a forward contract to sell 1,083.51 AUD for 1,083.51 × 0.96 = 1,040.17 USD.

The 1,020.41 AUD that are invested at 3% grow to $1{,}020.41e^{0.03\times 2} = 1{,}083.51$ AUD in 2 years. The forward contract has the effect of converting this to 1,040.17 USD. The amount needed to pay off the USD borrowings is $1{,}000e^{0.01\times 2} = 1{,}020.20$ USD. The strategy therefore gives rise to a riskless profit of 1,040.17 − 1,020.20 = 19.97 USD.

Table 8-4 shows currency futures quotes on May 14, 2013. The quotes are US dollars per unit of the foreign currency. (In the case of the Japanese yen, the quote is US dollars per 100 yen.) This is the usual quotation convention for futures contracts. Equation (8.9) applies with r equal to the US risk-free rate and r_f equal to the foreign risk-free rate.

On May 14, 2013, short-term interest rates on the Japanese yen, Swiss franc, and euro were lower than the short-term interest rate on the US dollar. This corresponds to the $r > r_f$ situation and explains why futures prices for these currencies increase with maturity in Table 8-4. For the Australian dollar, British pound, and Canadian dollar, short-term interest rates were higher than in the United States. This corresponds to the $r_f > r$ situation and explains why the futures settlement prices of these currencies decrease with maturity.

Example 8.7

In Table 8-4, the September settlement price for the Australian dollar is about 0.6% lower than the June settlement price. This indicates that the futures prices are decreasing

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TABLE 8-4 Futures Quotes for a Selection of CME Group Contracts on Foreign Currencies on May 14, 2013

	Open	High	Low	Prior Settlement	Last Trade	Change	Volume
Australian Dollar, USD per AUD, 100,000 AUD							
June 2013	0.9930	0.9980	0.9862	0.9930	0.9870	−0.0060	118,000
Sept. 2013	0.9873	0.9918	0.9801	0.9869	0.9808	−0.0061	535
British Pound, USD per GBP, 62,500 GBP							
June 2013	1.5300	1.5327	1.5222	1.5287	1.5234	−0.0053	112,406
Sept. 2013	1.5285	1.5318	1.5217	1.5279	1.5224	−0.0055	214
Canadian Dollar, USD per CAD, 100,000 CAD							
June 2013	0.9888	0.9903	0.9826	0.9886	0.9839	−0.0047	63,452
Sept. 2013	0.9867	0.9881	0.9805	0.9865	0.9819	−0.0046	564
Dec. 2013	0.9844	0.9859	0.9785	0.9844	0.9797	−0.0047	101
Euro, USD per EUR, 125,000 EUR							
June 2013	1.2983	1.3032	1.2932	1.2973	1.2943	−0.0030	257,103
Sept. 2013	1.2990	1.3039	1.2941	1.2981	1.2950	−0.0031	621
Dec. 2013	1.3032	1.3045	1.2953	1.2989	1.2957	−0.0032	81
Japanese Yen, USD per 100 Yen, 12.5 Million Yen							
June 2013	0.9826	0.9877	0.9770	0.9811	0.9771	−0.0040	160,395
Sept. 2013	0.9832	0.9882	0.9777	0.9816	0.9777	−0.0039	341
Swiss Franc, USD per CHF, 125,000 CHF							
June 2013	1.0449	1.0507	1.0358	1.0437	1.0368	−0.0069	41,463
Sept. 2013	1.0467	1.0512	1.0370	1.0446	1.0376	−0.0070	16

at about 2.4% per year with maturity. From Equation (8.9) this is an estimate of the amount by which short-term Australian interest rates exceeded short-term US interest rates on May 14, 2013.

A Foreign Currency as an Asset Providing a Known Yield

Equation (8.9) is identical to Equation (8.3) with q replaced by r_f. This is not a coincidence. A foreign currency can be regarded as an investment asset paying a known yield. The yield is the risk-free rate of interest in the foreign currency.

To understand this, we note that the value of interest paid in a foreign currency depends on the value of the foreign currency. Suppose that the interest rate on British pounds is 5% per annum. To a US investor the British pound provides an income equal to 5% of the value of the British pound per annum. In other words it is an asset that provides a yield of 5% per annum.

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FUTURES ON COMMODITIES

We now move on to consider futures contracts on commodities. First we look at the futures prices of commodities that are investment assets such as gold and silver.[6] We then go on to examine the futures prices of consumption assets.

Income and Storage Costs

As explained in Box 6-1, the hedging strategies of gold producers leads to a requirement on the part of investment banks to borrow gold. Gold owners such as central banks charge interest in the form of what is known as the *gold lease rate* when they lend gold. The same is true of silver. Gold and silver can therefore provide income to the holder. Like other commodities they also have storage costs.

Equation (8.1) shows that, in the absence of storage costs and income, the forward price of a commodity that is an investment asset is given by

$$F_0 = S_0 e^{rT} \tag{8.10}$$

Storage costs can be treated as negative income. If U is the present value of all the storage costs, net of income, during the life of a forward contract, it follows from Equation (8.2) that

$$F_0 = (S_0 + U)e^{rT} \tag{8.11}$$

Example 8.8

Consider a 1-year futures contract on an investment asset that provides no income. It costs $2 per unit to store the asset, with the payment being made at the end of the year. Assume that the spot price is $450 per unit and the risk-free rate is 7% per annum for all maturities. This corresponds to $r = 0.07$, $S_0 = 450$, $T = 1$, and

$$U = 2e^{-0.07\times 1} = 1.865$$

From Equation (8.11), the theoretical futures price, F_0, is given by

$$F_0 = (450 + 1.865)e^{0.07\times 1} = \$484.63$$

If the actual futures price is greater than 484.63, an arbitrageur can buy the asset and short 1-year futures contracts to lock in a profit. If the actual futures price is less than 484.63, an investor who already owns the asset can improve the return by selling the asset and buying futures contracts.

If the storage costs (net of income) incurred at any time are proportional to the price of the commodity, they can be treated as negative yield. In this case, from Equation (8.3),

$$F_0 = S_0 e^{(r+u)T} \tag{8.12}$$

where u denotes the storage costs per annum as a proportion of the spot price net of any yield earned on the asset.

Consumption Commodities

Commodities that are consumption assets rather than investment assets usually provide no income, but can be subject to significant storage costs. We now review the arbitrage strategies used to determine futures prices from spot prices carefully.[7]

Suppose that, instead of Equation (8.11), we have

$$F_0 > (S_0 + U)e^{rT} \tag{8.13}$$

To take advantage of this opportunity, an arbitrageur can implement the following strategy:

1. Borrow an amount $S_0 + U$ at the risk-free rate and use it to purchase one unit of the commodity and to pay storage costs.
2. Short a futures contract on one unit of the commodity.

If we regard the futures contract as a forward contract, so that there is no daily settlement, this strategy leads to a profit of $F_0 - (S_0 + U)e^{rT}$ at time T. There is no problem in implementing the strategy for any commodity. However, as arbitrageurs do so, there will be a tendency for S_0 to increase and F_0 to decrease until Equation (8.13) is no longer true. We conclude that Equation (8.13) cannot hold for any significant length of time.

Suppose next that

$$F_0 < (S_0 + U)e^{rT} \tag{8.14}$$

[6] Recall that, for an asset to be an investment asset, it need not be held solely for investment purposes. What is required is that some individuals hold it for investment purposes and that these individuals be prepared to sell their holdings and go long forward contracts, if the latter look more attractive. This explains why silver, although it has industrial uses, is an investment asset.

[7] For some commodities the spot price depends on the delivery location. We assume that the delivery location for spot and futures are the same.

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When the commodity is an investment asset, we can argue that many investors hold the commodity solely for investment. When they observe the inequality in Equation (8.14), they will find it profitable to do the following:

1. Sell the commodity, save the storage costs, and invest the proceeds at the risk-free interest rate.
2. Take a long position in a futures contract.

The result is a riskless profit at maturity of $(S_0 + U)e^{rT} - F_0$ relative to the position the investors would have been in if they had held the commodity. It follows that Equation (8.14) cannot hold for long. Because neither Equation (8.13) nor (8.14) can hold for long, we must have $F_0 = (S_0 + U)e^{rT}$.

This argument cannot be used for a commodity that is a consumption asset rather than an investment asset. Individuals and companies who own a consumption commodity usually plan to use it in some way. They are reluctant to sell the commodity in the spot market and buy forward or futures contracts, because forward and futures contracts cannot be used in a manufacturing process or consumed in some other way. There is therefore nothing to stop Equation (8.14) from holding, and all we can assert for a consumption commodity is

$$F_0 \leq (S_0 + U)e^{rT} \tag{8.15}$$

If storage costs are expressed as a proportion u of the spot price, the equivalent result is

$$F_0 \leq S_0 e^{(r+u)T} \tag{8.16}$$

Convenience Yields

We do not necessarily have equality in Equations (8.15) and (8.16) because users of a consumption commodity may feel that ownership of the physical commodity provides benefits that are not obtained by holders of futures contracts. For example, an oil refiner is unlikely to regard a futures contract on crude oil in the same way as crude oil held in inventory. The crude oil in inventory can be an input to the refining process, whereas a futures contract cannot be used for this purpose. In general, ownership of the physical asset enables a manufacturer to keep a production process running and perhaps profit from temporary local shortages. A futures contract does not do the same. The benefits from holding the physical asset are sometimes referred to as the *convenience yield* provided by the commodity. If the dollar amount of storage costs is known and has a present value U, then the convenience yield y is defined such that

$$F_0 e^{yT} = (S_0 + U)e^{rT}$$

If the storage costs per unit are a constant proportion, u, of the spot price, then y is defined so that

$$F_0 e^{yT} = S_0 e^{(r+u)T}$$

or

$$F_0 = S_0 e^{(r+u-y)T} \tag{8.17}$$

The convenience yield simply measures the extent to which the left-hand side is less than the right-hand side in Equation (8.15) or (8.16). For investment assets the convenience yield must be zero; otherwise, there are arbitrage opportunities. Table 5-2 in Chapter 5 shows that, on May 14, 2013, the futures price of soybeans decreased as the maturity of the contract increased from July 2013 to November 2013. This pattern suggests that the convenience yield, y, is greater than $r + u$ during this period.

The convenience yield reflects the market's expectations concerning the future availability of the commodity. The greater the possibility that shortages will occur, the higher the convenience yield. If users of the commodity have high inventories, there is very little chance of shortages in the near future and the convenience yield tends to be low. If inventories are low, shortages are more likely and the convenience yield is usually higher.

THE COST OF CARRY

The relationship between futures prices and spot prices can be summarized in terms of the *cost of carry*. This measures the storage cost plus the interest that is paid to finance the asset less the income earned on the asset. For a non-dividend-paying stock, the cost of carry is r, because there are no storage costs and no income is earned; for a stock index, it is $r - q$, because income is earned at rate q on the asset. For a currency, it is $r - r_f$; for a commodity that provides income at rate q and requires storage costs at rate u, it is $r - q + u$; and so on.

Define the cost of carry as c. For an investment asset, the futures price is

$$F_0 = S_0 e^{cT} \tag{8.18}$$

For a consumption asset, it is

$$F_0 = S_0 e^{(c-y)T} \tag{8.19}$$

where y is the convenience yield.

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DELIVERY OPTIONS

Whereas a forward contract normally specifies that delivery is to take place on a particular day, a futures contract often allows the party with the short position to choose to deliver at any time during a certain period. (Typically the party has to give a few days' notice of its intention to deliver.) The choice introduces a complication into the determination of futures prices. Should the maturity of the futures contract be assumed to be the beginning, middle, or end of the delivery period? Even though most futures contracts are closed out prior to maturity, it is important to know when delivery would have taken place in order to calculate the theoretical futures price.

If the futures price is an increasing function of the time to maturity, it can be seen from Equation (8.19) that $c > y$, so that the benefits from holding the asset (including convenience yield and net of storage costs) are less than the risk-free rate. It is usually optimal in such a case for the party with the short position to deliver as early as possible, because the interest earned on the cash received outweighs the benefits of holding the asset. As a rule, futures prices in these circumstances should be calculated on the basis that delivery will take place at the beginning of the delivery period. If futures prices are decreasing as time to maturity increases ($c < y$), the reverse is true. It is then usually optimal for the party with the short position to deliver as late as possible, and futures prices should, as a rule, be calculated on this assumption.

FUTURES PRICES AND EXPECTED FUTURE SPOT PRICES

We refer to the market's average opinion about what the spot price of an asset will be at a certain future time as the *expected spot price* of the asset at that time. Suppose that it is now June and the September futures price of corn is 350 cents. It is interesting to ask what the expected spot price of corn in September is. Is it less than 350 cents, greater than 350 cents, or exactly equal to 350 cents? As illustrated in Figure 5-1, the futures price converges to the spot price at maturity. If the expected spot price is less than 350 cents, the market must be expecting the September futures price to decline, so that traders with short positions gain and traders with long positions lose. If the expected spot price is greater than 350 cents, the reverse must be true. The market must be expecting the September futures price to increase, so that traders with long positions gain while those with short positions lose.

Keynes and Hicks

Economists John Maynard Keynes and John Hicks argued that, if hedgers tend to hold short positions and speculators tend to hold long positions, the futures price of an asset will be below the expected spot price.[8] This is because speculators require compensation for the risks they are bearing. They will trade only if they can expect to make money on average. Hedgers will lose money on average, but they are likely to be prepared to accept this because the futures contract reduces their risks. If hedgers tend to hold long positions while speculators hold short positions, Keynes and Hicks argued that the futures price will be above the expected spot price for a similar reason.

Risk and Return

The modern approach to explaining the relationship between futures prices and expected spot prices is based on the relationship between risk and expected return in the economy. In general, the higher the risk of an investment, the higher the expected return demanded by an investor. The capital asset pricing model, which is explained in the appendix to Chapter 6, shows that there are two types of risk in the economy: systematic and nonsystematic. Nonsystematic risk should not be important to an investor. It can be almost completely eliminated by holding a well-diversified portfolio. An investor should not therefore require a higher expected return for bearing nonsystematic risk. Systematic risk, in contrast, cannot be diversified away. It arises from a correlation between returns from the investment and returns from the whole stock market. An investor generally requires a higher expected return than the risk-free interest rate for bearing positive amounts of systematic risk. Also, an investor is prepared to accept a lower expected return than the risk-free interest rate when the systematic risk in an investment is negative.

[8] See: J. M. Keynes, *A Treatise on Money.* London: Macmillan, 1930; and J. R. Hicks, *Value and Capital.* Oxford: Clarendon Press, 1939.

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The Risk in a Futures Position

Let us consider a speculator who takes a long position in a futures contract that lasts for T years in the hope that the spot price of the asset will be above the futures price at the end of the life of the futures contract. We ignore daily settlement and assume that the futures contract can be treated as a forward contract. We suppose that the speculator puts the present value of the futures price into a risk-free investment while simultaneously taking a long futures position. The proceeds of the risk-free investment are used to buy the asset on the delivery date. The asset is then immediately sold for its market price. The cash flows to the speculator are as follows:

Today: $-F_0e^{-rT}$

End of futures contract: $+S_T$

where F_0 is the futures price today, S_T is the price of the asset at time T at the end of the futures contract, and r is the risk-free return on funds invested for time T.

How do we value this investment? The discount rate we should use for the expected cash flow at time T equals an investor's required return on the investment. Suppose that k is an investor's required return for this investment. The present value of this investment is

$$-F_0e^{-rT} + E(S_T)e^{-kT}$$

where E denotes expected value. We can assume that all investments in securities markets are priced so that they have zero net present value. This means that

$$-F_0e^{-rT} + E(S_T)e^{-kT} = 0$$

or

$$F_0 = E(S_T)e^{(r-k)T} \qquad \textbf{(8.20)}$$

As we have just discussed, the returns investors require on an investment depend on its systematic risk. The investment we have been considering is in essence an investment in the asset underlying the futures contract. If the returns from this asset are uncorrelated with the stock market, the correct discount rate to use is the risk-free rate r, so we should set $k = r$. Equation (8.20) then gives

$$F_0 = E(S_T)$$

This shows that the futures price is an unbiased estimate of the expected future spot price when the return from the underlying asset is uncorrelated with the stock market.

If the return from the asset is positively correlated with the stock market, $k > r$ and Equation (8.20) leads to $F_0 < E(S_T)$. This shows that, when the asset underlying the futures contract has positive systematic risk, we should expect the futures price to understate the expected future spot price. An example of an asset that has positive systematic risk is a stock index. The expected return of investors on the stocks underlying an index is generally more than the risk-free rate, r. The dividends provide a return of q. The expected increase in the index must therefore be more than $r - q$. Equation (8.8) is therefore consistent with the prediction that the futures price understates the expected future stock price for a stock index.

If the return from the asset is negatively correlated with the stock market, $k < r$ and Equation (8.20) gives $F_0 > E(S_T)$. This shows that, when the asset underlying the futures contract has negative systematic risk, we should expect the futures price to overstate the expected future spot price.

These results are summarized in Table 8-5.

Normal Backwardation and Contango

When the futures price is below the expected future spot price, the situation is known as *normal backwardation*; and when the futures price is above the expected future spot price, the situation is known as *contango*. However, it should be noted that sometimes these terms are used

TABLE 8-5 Relationship between Futures Price and Expected Future Spot Price

Underlying Asset	Relationship of Expected Return k from Asset to Risk-Free Rate r	Relationship of Futures Price F to Expected Future Spot Price $E(S_T)$
No systematic risk	$k = r$	$F_0 = E(S_T)$
Positive systematic risk	$k > r$	$F_0 < E(S_T)$
Negative systematic risk	$k < r$	$F_0 > E(S_T)$

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to refer to whether the futures price is below or above the current spot price, rather than the expected future spot price.

SUMMARY

For most purposes, the futures price of a contract with a certain delivery date can be considered to be the same as the forward price for a contract with the same delivery date. It can be shown that in theory the two should be exactly the same when interest rates are perfectly predictable.

For the purposes of understanding futures (or forward) prices, it is convenient to divide futures contracts into two categories: those in which the underlying asset is held for investment by at least some traders and those in which the underlying asset is held primarily for consumption purposes.

In the case of investment assets, we have considered three different situations:

1. The asset provides no income.
2. The asset provides a known dollar income.
3. The asset provides a known yield.

The results are summarized in Table 8-6. They enable futures prices to be obtained for contracts on stock indices, currencies, gold, and silver. Storage costs can be treated as negative income.

In the case of consumption assets, it is not possible to obtain the futures price as a function of the spot price and other observable variables. Here the parameter known as the asset's convenience yield becomes important. It measures the extent to which users of the commodity feel that ownership of the physical asset provides benefits that are not obtained by the holders of the futures contract. These benefits may include the ability to profit from temporary local shortages or the ability to keep a production process running. We can obtain an upper bound for the futures price of consumption assets using arbitrage arguments, but we cannot nail down an equality relationship between futures and spot prices.

The concept of cost of carry is sometimes useful. The cost of carry is the storage cost of the underlying asset plus the cost of financing it minus the income received from it. In the case of investment assets, the futures price is greater than the spot price by an amount reflecting the cost of carry. In the case of consumption assets, the futures price is greater than the spot price by an amount reflecting the cost of carry net of the convenience yield.

TABLE 8-6 Summary of Results for a Contract with Time to Maturity T on an Investment Asset with Price S_0 When the Risk-Free Interest Rate for a T-Year Period Is r

Asset	Forward/ Futures Price	Value of Long Forward Contract with Delivery Price K
Provides no income:	S_0e^{rT}	$S_0 - Ke^{-rT}$
Provides known income with present value I:	$(S_0 - I)e^{rT}$	$S_0 - I - Ke^{-rT}$
Provides known yield q:	$S_0e^{(r-q)T}$	$S_0e^{-qT} - Ke^{-rT}$

If we assume the capital asset pricing model is true, the relationship between the futures price and the expected future spot price depends on whether the return on the asset is positively or negatively correlated with the return on the stock market. Positive correlation will tend to lead to a futures price lower than the expected future spot price, whereas negative correlation will tend to lead to a futures price higher than the expected future spot price. Only when the correlation is zero will the theoretical futures price be equal to the expected future spot price.

Further Reading

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Interest Rate Futures

9

Learning Objectives

After completing this reading you should be able to:

- Identify the most commonly used day count conventions, describe the markets that each one is typically used in, and apply each to an interest calculation.
- Calculate the conversion of a discount rate to a price for a US Treasury bill.
- Differentiate between the clean and dirty price for a US Treasury bond; calculate the accrued interest and dirty price on a US Treasury bond.
- Explain and calculate a US Treasury bond futures contract conversion factor.
- Calculate the cost of delivering a bond into a Treasury bond futures contract.
- Describe the impact of the level and shape of the yield curve on the cheapest-to-deliver Treasury bond decision.
- Calculate the theoretical futures price for a Treasury bond futures contract.
- Calculate the final contract price on a Eurodollar futures contract.
- Describe and compute the Eurodollar futures contract convexity adjustment.
- Explain how Eurodollar futures can be used to extend the LIBOR zero curve.
- Calculate the duration-based hedge ratio, and create a duration-based hedging strategy using interest rate futures.
- Explain the limitations of using a duration-based hedging strategy.

Excerpt is Chapter 6 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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So far we have covered futures contracts on commodities, stock indices, and foreign currencies. We have seen how they work, how they are used for hedging, and how futures prices are determined. We now move on to consider interest rate futures.

This chapter explains the popular Treasury bond and Eurodollar futures contracts that trade in the United States. Many of the other interest rate futures contracts throughout the world have been modeled on these contracts. The chapter also shows how interest rate futures contracts, when used in conjunction with the duration measure introduced in Chapter 7, can be used to hedge a company's exposure to interest rate movements.

DAY COUNT AND QUOTATION CONVENTIONS

As a preliminary to the material in this chapter, we consider the day count and quotation conventions that apply to bonds and other instruments dependent on the interest rate.

Day Counts

The day count defines the way in which interest accrues over time. Generally, we know the interest earned over some reference period (e.g., the time between coupon payments on a bond), and we are interested in calculating the interest earned over some other period.

The day count convention is usually expressed as *X/Y*. When we are calculating the interest earned between two dates, *X* defines the way in which the number of days between the two dates is calculated, and *Y* defines the way in which the total number of days in the reference period is measured. The interest earned between the two dates is

$$\frac{\text{Number of days between dates}}{\text{Number of days in reference period}} \times \text{Interest earned in reference period}$$

Three day count conventions that are commonly used in the United States are:

1. Actual/actual (in period)
2. 30/360
3. Actual/360

BOX 9-1 Day Counts Can Be Deceptive

Between February 28 and March 1, 2015, you have a choice between owning a US government bond and a US corporate bond. They pay the same coupon and have the same quoted price. Assuming no risk of default, which would you prefer?

It sounds as though you should be indifferent, but in fact you should have a marked preference for the corporate bond. Under the 30/360 day count convention used for corporate bonds, there are 3 days between February 28, 2015, and March 1, 2015. Under the actual/actual (in period) day count convention used for government bonds, there is only 1 day. You would earn approximately three times as much interest by holding the corporate bond!

The actual/actual (in period) day count is used for Treasury bonds in the United States. This means that the interest earned between two dates is based on the ratio of the actual days elapsed to the actual number of days in the period between coupon payments. Assume that the bond principal is $100, coupon payment dates are March 1 and September 1, and the coupon rate is 8% per annum. (This means that $4 of interest is paid on each of March 1 and September 1.) Suppose that we wish to calculate the interest earned between March 1 and July 3. The reference period is from March 1 to September 1. There are 184 (actual) days in the reference period, and interest of $4 is earned during the period. There are 124 (actual) days between March 1 and July 3. The interest earned between March 1 and July 3 is therefore

$$\frac{124}{184} \times 4 = 2.6957$$

The 30/360 day count is used for corporate and municipal bonds in the United States. This means that we assume 30 days per month and 360 days per year when carrying out calculations. With the 30/360 day count, the total number of days between March 1 and September 1 is 180. The total number of days between March 1 and July 3 is $(4 \times 30) + 2 = 122$. In a corporate bond with the same terms as the Treasury bond just considered, the interest earned between March 1 and July 3 would therefore be

$$\frac{122}{180} \times 4 = 2.7111$$

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As shown in Box 9-1, sometimes the 30/360 day count convention has surprising consequences.

The actual/360 day count is used for money market instruments in the United States. This indicates that the reference period is 360 days. The interest earned during part of a year is calculated by dividing the actual number of elapsed days by 360 and multiplying by the rate. The interest earned in 90 days is therefore exactly one-fourth of the quoted rate, and the interest earned in a whole year of 365 days is 365/360 times the quoted rate.

Conventions vary from country to country and from instrument to instrument. For example, money market instruments are quoted on an actual/365 basis in Australia, Canada, and New Zealand. LIBOR is quoted on an actual/360 for all currencies except sterling, for which it is quoted on an actual/365 basis. Euro-denominated and sterling bonds are usually quoted on an actual/actual basis.

Price Quotations of US Treasury Bills

The prices of money market instruments are sometimes quoted using a *discount rate.* This is the interest earned as a percentage of the final face value rather than as a percentage of the initial price paid for the instrument. An example is Treasury bills in the United States. If the price of a 91-day Treasury bill is quoted as 8, this means that the rate of interest earned is 8% of the face value per 360 days. Suppose that the face value is $100. Interest of $2.0222 (= $100 × 0.08 × 91/360) is earned over the 91-day life. This corresponds to a true rate of interest of 2.0222/(100 − 2.0222) = 2.064% for the 91-day period. In general, the relationship between the cash price per $100 of face value and the quoted price of a Treasury bill in the United States is

$$P = \frac{360}{n}(100 - Y)$$

where P is the quoted price, Y is the cash price, and n is the remaining life of the Treasury bill measured in calendar days. For example, when the cash price of a 90-day Treasury bill is 99, the quoted price is 4.

Price Quotations of US Treasury Bonds

Treasury bond prices in the United States are quoted in dollars and thirty-seconds of a dollar. The quoted price is for a bond with a face value of $100. Thus, a quote of 90-05 or 90 5/32 indicates that the quoted price for a bond with a face value of $100,000 is $90,156.25.

The quoted price, which traders refer to as the *clean price*, is not the same as the cash price paid by the purchaser of the bond, which is referred to by traders as the *dirty price*. In general,

$$\text{Cash price} = \text{Quoted price} + \text{Accrued interest since last coupon date}$$

To illustrate this formula, suppose that it is March 5, 2015, and the bond under consideration is an 11% coupon bond maturing on July 10, 2038, with a quoted price of 95-16 or $95.50. Because coupons are paid semiannually on government bonds (and the final coupon is at maturity), the most recent coupon date is January 10, 2015, and the next coupon date is July 10, 2015. The (actual) number of days between January 10, 2015, and March 5, 2015, is 54, whereas the (actual) number of days between January 10, 2015, and July 10, 2015, is 181. On a bond with $100 face value, the coupon payment is $5.50 on January 10 and July 10. The accrued interest on March 5, 2015, is the share of the July 10 coupon accruing to the bondholder on March 5, 2015. Because actual/actual in period is used for Treasury bonds in the United States, this is

$$\frac{54}{181} \times \$5.50 = \$1.64$$

The cash price per $100 face value for the bond is therefore

$$\$95.50 + \$1.64 = \$97.14$$

Thus, the cash price of a $100,000 bond is $97,140.

TREASURY BOND FUTURES

Table 9-1 shows interest rate futures quotes on May 14, 2013. One of the most popular long-term interest rate futures contracts is the Treasury bond futures contract traded by the CME Group. In this contract, any government bond that has between 15 and 25 years to maturity on the first day of the delivery month can be delivered. A contract which the CME Group started trading 2010 is the ultra T-bond contract, where any bond with maturity over 25 years can be delivered.

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TABLE 9-1 Futures Quotes for a Selection of CME Group Contracts on Interest Rates on May 14, 2013

	Open	High	Low	Prior Settlement	Last Trade	Change	Volume
Ultra T-Bond, $100,000							
June 2013	158-08	158-31	156-31	158-08	157-00	−1-08	45,040
Sept. 2013	157-12	157-15	155-16	156-24	155-18	−1-06	176
Treasury Bonds, $100,000							
June 2013	144-22	145-04	143-26	144-20	143-28	−0-24	346,878
Sept. 2013	143-28	144-08	142-30	143-24	142-31	−0-25	2,455
10-Year Treasury Notes, $100,000							
June 2013	131-315	132-050	131-205	131-310	131-210	−0-100	1,151,825
Sept. 2013	131-040	131-080	130-240	131-025	130-240	−0-105	20,564
5-Year Treasury Notes, $100,000							
June 2013	123-310	124-015	123-267	123-307	123-267	−0-040	478,993
Sept. 2013	123-177	123-192	123-122	123-165	123-122	−0-042	4,808
2-Year Treasury Notes, $200,000							
June 2013	110-080	110-085	110-075	110-080	110-075	−0-005	98,142
Sept. 2013	110-067	110-072	110-067	110-070	110-067	−0-002	13,103
30-Day Fed Funds Rate, $5,000,000							
Sept. 2013	99.875	99.880	99.875	99.875	99.875	0.000	956
July 2014	99.830	99.835	99.830	99.830	99.830	0.000	1,030
Eurodollar, $1,000,000							
June 2013	99.720	99.725	99.720	99.725	99.720	−0.005	107,167
Sept. 2013	99.700	99.710	99.700	99.705	99.700	−0.005	114,055
Dec. 2013	99.675	99.685	99.670	99.675	99.670	−0.005	144,213
Dec. 2015	99.105	99.125	99.080	99.100	99.080	−0.020	96,933
Dec. 2017	97.745	97.770	97.675	97.730	97.680	−0.050	14,040
Dec. 2019	96.710	96.775	96.690	96.760	96.690	−0.070	23

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The 10-year, 5-year, and 2-year Treasury note futures contract in the United States are also very popular. In the 10-year Treasury note futures contract, any government bond (or note) with a maturity between 6½ and 10 years can be delivered. In the 5-year and 2-year Treasury note futures contracts, the note delivered has a remaining life of about 5 years and 2 years, respectively (and the original life must be less than 5.25 years).

As will be explained later in this section, the exchange has developed a procedure for adjusting the price received by the party with the short position according to the particular bond or note it chooses to deliver. The remaining discussion in this section focuses on the Treasury bond futures. Many other contracts traded in the United States and the rest of the world are designed in a similar way to the Treasury bond futures, so that many of the points we will make are applicable to these contracts as well.

Quotes

Ultra T-bond futures and Treasury bond futures contracts are quoted in dollars and thirty-seconds of a dollar per $100 face value. This is similar to the way the bonds are quoted in the spot market. In Table 9-1, the settlement price of the June 2013 Treasury bond futures contract is specified as 144-20. This means $144^{20}/_{32}$, or 144.625. The settlement price of the 10-year Treasury note futures contract is quoted to the nearest half of a thirty-second. Thus the settlement price of 131-025 for the September 2013 contract should be interpreted as $131^{2.5}/_{32}$, or 131.078125. The 5-year and 2-year Treasury note contracts are quoted even more precisely, to the nearest quarter of a thirty-second. Thus the settlement price of 123-307 for the June 5-year Treasury note contract should be interpreted as $123^{30.75}/_{32}$, or 123.9609375. Similarly, the trade price of 123-122 for the September contract should be interpreted as $123^{12.25}/_{32}$, or 123.3828125.

Conversion Factors

As mentioned, the Treasury bond futures contract allows the party with the short position to choose to deliver any bond that has a maturity between 15 and 25 years. When a particular bond is delivered, a parameter known as its *conversion factor* defines the price received for the bond by the party with the short position. The applicable quoted price for the bond delivered is the product of the conversion factor and the most recent settlement price for the futures contract. Taking accrued interest into account, the cash received for each $100 face value of the bond delivered is

$$(\text{Most recent settlement price} \times \text{Conversion factor}) + \text{Accrued interest}$$

Each contract is for the delivery of $100,000 face value of bonds. Suppose that the most recent settlement price is 90-00, the conversion factor for the bond delivered is 1.3800, and the accrued interest on this bond at the time of delivery is $3 per $100 face value. The cash received by the party with the short position (and paid by the party with the long position) is then

$$(1.3800 \times 90.00) + 3.00 = \$127.20$$

per $100 face value. A party with the short position in one contract would deliver bonds with a face value of $100,000 and receive $127,200.

The conversion factor for a bond is set equal to the quoted price the bond would have per dollar of principal on the first day of the delivery month on the assumption that the interest rate for all maturities equals 6% per annum (with semiannual compounding). The bond maturity and the times to the coupon payment dates are rounded down to the nearest 3 months for the purposes of the calculation. The practice enables the exchange to produce comprehensive tables. If, after rounding, the bond lasts for an exact number of 6-month periods, the first coupon is assumed to be paid in 6 months. If, after rounding, the bond does not last for an exact number of 6-month periods (i.e., there are an extra 3 months), the first coupon is assumed to be paid after 3 months and accrued interest is subtracted.

As a first example of these rules, consider a 10% coupon bond with 20 years and 2 months to maturity. For the purposes of calculating the conversion factor, the bond is assumed to have exactly 20 years to maturity. The first coupon payment is assumed to be made after 6 months. Coupon payments are then assumed to be made at 6-month intervals until the end of the 20 years when the principal payment is made. Assume that the face value is $100. When the discount rate is 6% per annum with semiannual compounding (or 3% per 6 months), the value of the bond is

$$\sum_{i=1}^{40} \frac{5}{1.03^i} + \frac{100}{1.03^{40}} = \$146.23$$

Dividing by the face value gives a conversion factor of 1.4623.

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As a second example of the rules, consider an 8% coupon bond with 18 years and 4 months to maturity. For the purposes of calculating the conversion factor, the bond is assumed to have exactly 18 years and 3 months to maturity. Discounting all the payments back to a point in time 3 months from today at 6% per annum (compounded semiannually) gives a value of

$$4+\sum_{i=1}^{36}\frac{4}{1.03^{i}}+\frac{100}{1.03^{36}}=\$125.83$$

The interest rate for a 3-month period is $\sqrt{1.03}-1$, or 1.4889%. Hence, discounting back to the present gives the bond's value as 125.83/1.014889 = $123.99. Subtracting the accrued interest of 2.0, this becomes $121.99. The conversion factor is therefore 1.2199.

Cheapest-to-Deliver Bond

At any given time during the delivery month, there are many bonds that can be delivered in the Treasury bond futures contract. These vary widely as far as coupon and maturity are concerned. The party with the short position can choose which of the available bonds is "cheapest" to deliver. Because the party with the short position receives

(Most recent settlement price × Conversion factor) + Accrued interest

and the cost of purchasing a bond is

Quoted bond price + Accrued interest

the cheapest-to-deliver bond is the one for which

Quoted bond price − (Most recent settlement price × Conversion factor)

is least. Once the party with the short position has decided to deliver, it can determine the cheapest-to-deliver bond by examining each of the deliverable bonds in turn.

Example 9.1

The party with the short position has decided to deliver and is trying to choose between the three bonds in the table below. Assume the most recent settlement price is 93-08, or 93.25.

Bond	Quoted Bond Price ($)	Conversion Factor
1	99.50	1.0382
2	143.50	1.5188
3	119.75	1.2615

The cost of delivering each of the bonds is as follows:

Bond 1: 99.50 − (93.25 × 1.0382) = $2.69

Bond 2: 143.50 − (93.25 × 1.5188) = $1.87

Bond 3: 119.75 − (93.25 × 1.2615) = $2.12

The cheapest-to-deliver bond is Bond 2.

A number of factors determine the cheapest-to-deliver bond. When bond yields are in excess of 6%, the conversion factor system tends to favor the delivery of low-coupon long-maturity bonds. When yields are less than 6%, the system tends to favor the delivery of high-coupon short-maturity bonds. Also, when the yield curve is upward-sloping, there is a tendency for bonds with a long time to maturity to be favored, whereas when it is downward-sloping, there is a tendency for bonds with a short time to maturity to be delivered.

In addition to the cheapest-to-deliver bond option, the party with a short position has an option known as the wild card play. This is described in Box 9-2.

Determining the Futures Price

An exact theoretical futures price for the Treasury bond contract is difficult to determine because the short party's

BOX 9-2 The Wild Card Play

The settlement price in the CME Group's Treasury bond futures contract is the price at 2:00 p.m. Chicago time. However, Treasury bonds continue trading in the spot market beyond this time and a trader with a short position can issue to the clearing house a notice of intention to deliver later in the day. If the notice is issued, the invoice price is calculated on the basis of the settlement price that day, that is, the price at 2:00 p.m.

This practice gives rise to an option known as the *wild card play*. If bond prices decline after 2:00 p.m. on the first day of the delivery month, the party with the short position can issue a notice of intention to deliver at, say, 3:45 p.m. and proceed to buy bonds in the spot market for delivery at a price calculated from the 2:00 p.m. futures price. If the bond price does not decline, the party with the short position keeps the position open and waits until the next day when the same strategy can be used.

As with the other options open to the party with the short position, the wild card play is not free. Its value is reflected in the futures price, which is lower than it would be without the option.

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options concerned with the timing of delivery and choice of the bond that is delivered cannot easily be valued. However, if we assume that both the cheapest-to-deliver bond and the delivery date are known, the Treasury bond futures contract is a futures contract on a traded security (the bond) that provides the holder with known income.[1] Equation (8.2) then shows that the futures price, F_0, is related to the spot price, S_0, by

$$F_0 = (S_0 - I)e^{rT} \tag{9.1}$$

where I is the present value of the coupons during the life of the futures contract, T is the time until the futures contract matures, and r is the risk-free interest rate applicable to a time period of length T.

Example 9.2

Suppose that, in a Treasury bond futures contract, it is known that the cheapest-to-deliver bond will be a 12% coupon bond with a conversion factor of 1.6000. Suppose also that it is known that delivery will take place in 270 days. Coupons are payable semiannually on the bond. As illustrated in Figure 9-1, the last coupon date was 60 days ago, the next coupon date is in 122 days, and the coupon date thereafter is in 305 days. The term structure is flat, and the rate of interest (with continuous compounding) is 10% per annum. Assume that the current quoted bond price is $115. The cash price of the bond is obtained by adding to this quoted price the proportion of the next coupon payment that accrues to the holder. The cash price is therefore

$$115 + \frac{60}{60 + 122} \times 6 = 116.978$$

A coupon of $6 will be received after 122 days (= 0.3342 years). The present value of this is

$$6e^{-0.1\times 0.3342} = 5.803$$

The futures contract lasts for 270 days (= 0.7397 years). The cash futures price, if the contract were written on the 12% bond, would therefore be

$$(116.978 - 5.803)e^{0.1\times 0.7397} = 119.711$$

[1] In practice, for the purposes of estimating the cheapest-to-deliver bond, analysts usually assume that zero rates at the maturity of the futures contract will equal today's forward rates.

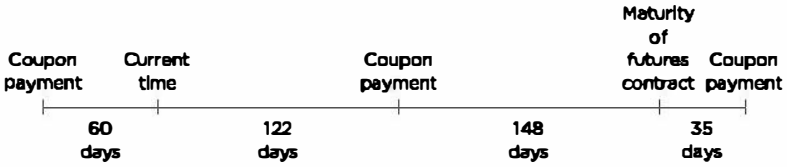

FIGURE 9-1 Time chart for Example 9.2.

At delivery, there are 148 days of accrued interest. The quoted futures price, if the contract were written on the 12% bond, is calculated by subtracting the accrued interest

$$119.711 - 6 \times \frac{148}{148 + 35} = 114.859$$

From the definition of the conversion factor, 1.6000 standard bonds are considered equivalent to each 12% bond. The quoted futures price should therefore be

$$\frac{114.859}{1.6000} = 71.79$$

EURODOLLAR FUTURES

The most popular interest rate futures contract in the United States is the three-month Eurodollar futures contract traded by the CME Group. A Eurodollar is a dollar deposited in a US or foreign bank outside the United States. The Eurodollar interest rate is the rate of interest earned on Eurodollars deposited by one bank with another bank. It is essentially the same as the London Interbank Offered Rate (LIBOR) introduced in Chapter 7.

A three-month Eurodollar futures contract is a futures contract on the interest that will be paid (by someone who borrows at the Eurodollar interest rate) on $1 million for a future three-month period. It allows a trader to speculate on a future three-month interest rate or to hedge an exposure to a future three-month interest rate. Eurodollar futures contracts have maturities in March, June, September, and December for up to 10 years into the future. This means that in 2014 a trader can use Eurodollar futures to take a position on what interest rates will be as far into the future as 2024. Short-maturity contracts trade for months other than March, June, September, and December.

To understand how Eurodollar futures contracts work, consider the June 2013 contract in Table 9-1. The

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settlement price on May 13, 2013, is 99.725. The last trading day is two days before the third Wednesday of the delivery month, which in the case of this contract is June 17, 2013. The contract is settled daily in the usual way until the last trading day. At 11 a.m. on the last trading day, there is a final settlement equal to 100 − *R*, where *R* is the three-month LIBOR fixing on that day, expressed with quarterly compounding and an actual/360 day count convention. Thus, if the three-month Eurodollar interest rate on June 17, 2013, turned out to be 0.75% (actual/360 with quarterly compounding), the final settlement price would be 99.250. Once a final settlement has taken place, all contracts are declared closed.

TABLE 9-2 Possible Sequence of Prices for June 2013 Eurodollar Futures Contract

Date	Settlement Futures Price	Change	Gain per Contract ($)
May 13, 2013	99.725		
May 14, 2013	99.720	−0.005	−12.50
May 15, 2013	99.670	−0.050	−125.00
⋮	⋮	⋮	⋮
June 17, 2013	99.615	+0.010	+25.00
Total		−0.110	−275.00

The contract is designed so that a one-basis-point (= 0.01) move in the futures quote corresponds to a gain or loss of $25 per contract. When a Eurodollar futures quote increases by one basis point, a trader who is long one contract gains $25 and a trader who is short one contract loses $25. Similarly, when the quote decreases by one basis point a trader who is long one contract loses $25 and a trader who is short one contract gains $25. Suppose, for example, a settlement price changes from 99.725 to 99.685. Traders with long positions lose 4 × 25 = $100 per contract; traders with short positions gain $100 per contract. A one-basis-point change in the futures quote corresponds to a 0.01% change in the underlying interest rate. This in turn leads to a

$$1{,}000{,}000 \times 0.0001 \times 0.25 = 25$$

or $25 change in the interest that will be earned on $1 million in three months. The $25 per basis point rule is therefore consistent with the point made earlier that the contract locks in an interest rate on $1 million for three months.

The futures quote is 100 minus the futures interest rate. An investor who is long gains when interest rates fall and one who is short gains when interest rates rise. Table 9-2 shows a possible set of outcomes for the June 2013 contract in Table 9-1 for a trader who takes a long position at the May 13, 2013, settlement price.

The contract price is defined as

$$10{,}000 \times \left[100 - 0.25 \times (100 - Q)\right] \qquad \textbf{(9.2)}$$

where Q is the quote. Thus, the settlement price of 99.725 for the June 2013 contract in Table 9-1 corresponds to a contract price of

$$10{,}000 \times \left[100 - 0.25 \times (100 - 99.725)\right] = \$999{,}312.5$$

In Table 9-2, the final contract price is

$$10{,}000 \times \left[100 - 0.25 \times (100 - 99.615)\right] = \$999{,}037.5$$

and the difference between the initial and final contract price is $275, This is consistent with the loss calculated in Table 9-2 using the "$25 per one-basis-point move" rule.

Example 9.3

An investor wants to lock in the interest rate for a three-month period beginning two days before the third Wednesday of September, on a principal of $100 million. We suppose that the September Eurodollar futures quote is 96.50, indicating that the investor can lock in an interest rate of 100 − 96.5 or 3.5% per annum. The investor hedges by buying 100 contracts. Suppose that, two days before the third Wednesday of September, the three-month Eurodollar rate turns out to be 2.6%. The final settlement in the contract is then at a price of 97.40. The investor gains

$$100 \times 25 \times (9{,}740 - 9{,}650) = 225{,}000$$

or $225,000 on the Eurodollar futures contracts. The interest earned on the three-month investment is

$$100{,}000{,}000 \times 0.25 \times 0.026 = 650{,}000$$

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or $650,000. The gain on the Eurodollar futures brings this up to $875,000, which is what the interest would be at 3.5% (100,000,000 × 0.25 × 0.035 = 875,000).

It appears that the futures trade has the effect of exactly locking an interest rate of 3.5% in all circumstances. In fact, the hedge is less than perfect because (a) futures contracts are settled daily (not all at the end) and (b) the final settlement in the futures contract happens at contract maturity, whereas the interest payment on the investment is three months later. One approximate adjustment for the second point is to reduce the size of the hedge to reflect the difference between funds received in September, and funds received three months later. In this case, we would assume an interest rate of 3.5% for the three-month period and multiply the number of contracts by 1/(1 + 0.035 × 0.25) = 0.9913. This would lead to 99 rather than 100 contracts being purchased.

Table 9-1 shows that the interest rate term structure in the US was upward sloping in May 2013. Using the "Prior Settlement" column, the futures rates for three-month periods beginning June 17, 2013, September 16, 2013, December 16, 2013, December 14, 2015, December 18, 2017, and December 16, 2019, were 0.275%, 0.295%, 0.325%, 0.900%, 2.270%, and 3.240%, respectively.

Example 9.3 shows how Eurodollar futures contracts can be used by an investor who wants to hedge the interest that will be earned during a future three-month period. Note that the timing of the cash flows from the hedge does not line up exactly with the timing of the interest cash flows. This is because the futures contract is settled daily. Also, the final settlement is in September, whereas interest payments on the investment are received three months later in December. As indicated in the example, a small adjustment can be made to the hedge position to approximately allow for this second point.

Other contracts similar to the CME Group's Eurodollar futures contracts trade on interest rates in other countries. The CME Group trades Euroyen contracts. The London International Financial Futures and Options Exchange (part of Euronext) trades three-month Euribor contracts (i.e., contracts on the three-month rate for euro deposits between euro zone banks) and three-month Euroswiss futures.

Forward vs. Futures Interest Rates

The Eurodollar futures contract is similar to a forward rate agreement (FRA: see Chapter 7) in that it locks in an interest rate for a future period. For short maturities (up to a year or so), the Eurodollar futures interest rate can be assumed to be the same as the corresponding forward interest rate. For longer-dated contracts, differences between the contracts become important. Compare a Eurodollar futures contract on an interest rate for the period between times T_1 and T_2 with an FRA for the same period. The Eurodollar futures contract is settled daily. The final settlement is at time T_1 and reflects the realized interest rate for the period between times T_1 and T_2. By contrast the FRA is not settled daily and the final settlement reflecting the realized interest rate between times T_1 and T_2 is made at time T_2.[2]

There are therefore two differences between a Eurodollar futures contract and an FRA. These are:

1. The difference between a Eurodollar futures contract and a similar contract where there is no daily settlement. The latter is a hypothetical forward contract where a payoff equal to the difference between the forward interest rate and the realized interest rate is paid at time T_1.
2. The difference between the hypothetical forward contract where there is settlement at time T_1 and a true forward contract where there is settlement at time T_2 equal to the difference between the forward interest rate and the realized interest rate.

These two components to the difference between the contracts cause some confusion in practice. Both decrease the forward rate relative to the futures rate, but for long-dated contracts the reduction caused by the second difference is much smaller than that caused by the first. The reason why the first difference (daily settlement) decreases the forward rate follows from the arguments in Chapter 8. Suppose you have a contract where the payoff is $R_M - R_F$ at time T_1, where R_F is a predetermined rate for the period between T_1 and T_2 and R_M is the realized rate for this period, and you have the option to switch to daily

[2] As mentioned in Chapter 7, settlement may occur at time T_1, but it is then equal to the present value of what the forward contract payoff would be at time T_2.

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settlement. In this case daily settlement tends to lead to cash inflows when rates are high and cash outflows when rates are low. You would therefore find switching to daily settlement to be attractive because you tend to have more money in your margin account when rates are high. As a result the market would therefore set R_F higher for the daily settlement alternative (reducing your cumulative expected payoff). To put this the other way round, switching from daily settlement to settlement at time T_1 reduces R_F.

To understand the reason why the second difference reduces the forward rate, suppose that the payoff of $R_M - R_F$ is at time T_2 instead of T_1 (as it is for a regular FRA). If R_M is high, the payoff is positive. Because rates are high, the cost to you of having the payoff that you receive at time T_2 rather than time T_1 is relatively high. If R_M is low, the payoff is negative. Because rates are low, the benefit to you of having the payoff you make at time T_2 rather than time T_1 is relatively low. Overall you would rather have the payoff at time T_1. If it is at time T_2 rather than T_1, you must be compensated by a reduction in R_F.

Convexity Adjustment

Analysts make what is known as a *convexity adjustment* to account for the total difference between the two rates. One popular adjustment is[3]

$$\text{Forward rate} = \text{Futures rate} - \frac{1}{2}\sigma^2 T_1 T_2 \qquad \textbf{(9.3)}$$

where, as above, T_1 is the time to maturity of the futures contract and T_2 is the time to the maturity of the rate underlying the futures contract. The variable σ is the standard deviation of the change in the short-term interest rate in 1 year. Both rates are expressed with continuous compounding.[4]

Example 9.4

Consider the situation where $\sigma = 0.012$ and we wish to calculate the forward rate when the 8-year Eurodollar futures price quote is 94. In this case $T_1 = 8$, $T_2 = 8.25$, and the convexity adjustment is

$$\frac{1}{2} \times 0.012^2 \times 8 \times 8.25 = 0.00475$$

or 0.475% (47.5 basis points). The futures rate is 6% per annum on an actual/360 basis with quarterly compounding. This corresponds to 1.5% per 90 days or an annual rate of (365/90) ln 1.015 = 6.038% with continuous compounding and an actual/365 day count. The estimate of the forward rate given by Equation (9.3), therefore, is 6.038 − 0.475 = 5.563% per annum with continuous compounding.

The table below shows how the size of the adjustment increases with the time to maturity.

Maturity of Futures (Years)	Convexity Adjustments (Basis Points)
2	3.2
4	12.2
6	27.0
8	47.5
10	73.8

We can see from this table that the size of the adjustment is roughly proportional to the square of the time to maturity of the futures contract. For example, when the maturity doubles from 2 to 4 years, the size of the convexity approximately quadruples.

Using Eurodollar Futures to Extend the LIBOR Zero Curve

The LIBOR zero curve out to 1 year is determined by the 1-month, 3-month, 6-month, and 12-month LIBOR rates. Once the convexity adjustment just described has been made, Eurodollar futures are often used to extend the zero curve. Suppose that the ith Eurodollar futures contract matures at time T_i ($i = 1, 2, \ldots$). It is usually assumed that the forward interest rate calculated from the ith futures contract applies to the period T_i to T_{i+1}. (In practice this is close to true.) This enables a bootstrap procedure to be used to determine zero rates. Suppose that F_i is the forward rate calculated from the ith Eurodollar futures contract and R_i is the zero rate for a maturity T_i. From Equation (7.5),

$$F_i = \frac{R_{i+1}T_{i+1} - R_i T_i}{T_{i+1} - T_i}$$

[3] See Technical Note 1 at www.rotman.utoronto.ca/~hull/TechnicalNotes for a proof of this.

[4] This formula is based on the Ho–Lee interest rate model. See T.S.Y. Ho and S.-B. Lee, "Term structure movements and pricing interest rate contingent claims," *Journal of Finance*, 41 (December 1986), 1011–29.

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so that

$$R_{I+1} = \frac{F_I(T_{I+1} - T_I) + R_I T_I}{T_{I+1}} \tag{9.4}$$

Other Euro rates such as Euroswiss, Euroyen, and Euribor are used in a similar way.

Example 9.5

The 400-day LIBOR zero rate has been calculated as 4.80% with continuous compounding and, from Eurodollar futures quotes, it has been calculated that (a) the forward rate for a 90-day period beginning in 400 days is 5.30% with continuous compounding, (b) the forward rate for a 90-day period beginning in 491 days is 5.50% with continuous compounding, and (c) the forward rate for a 90-day period beginning in 589 days is 5.60% with continuous compounding. We can use Equation (9.4) to obtain the 491-day rate as

$$\frac{0.053 \times 91 + 0.048 \times 400}{491} = 0.04893$$

or 4.893%. Similarly we can use the second forward rate to obtain the 589-day rate as

$$\frac{0.055 \times 98 + 0.04893 \times 491}{589} = 0.04994$$

or 4.994%. The next forward rate of 5.60% would be used to determine the zero curve out to the maturity of the next Eurodollar futures contract. (Note that, even though the rate underlying the Eurodollar futures contract is a 90-day rate, it is assumed to apply to the 91 or 98 days elapsing between Eurodollar contract maturities.)

DURATION-BASED HEDGING STRATEGIES USING FUTURES

We discussed duration in Chapter 7. Consider the situation where a position in an asset that is interest rate dependent, such as a bond portfolio or a money market security, is being hedged using an interest rate futures contract. Define:

- V_F: Contract price for one interest rate futures contract
- D_F: Duration of the asset underlying the futures contract at the maturity of the futures contract
- P: Forward value of the portfolio being hedged at the maturity of the hedge (in practice, this is usually assumed to be the same as the value of the portfolio today)
- D_P: Duration of the portfolio at the maturity of the hedge

If we assume that the change in the yield, Δy, is the same for all maturities, which means that only parallel shifts in the yield curve can occur, it is approximately true that

$$\Delta P = -PD_P \Delta y$$

It is also approximately true that

$$\Delta V_F = -V_F D_F \Delta y$$

The number of contracts required to hedge against an uncertain Δy, therefore, is

$$N^* = \frac{PD_P}{V_F D_F} \tag{9.5}$$

This is the *duration-based hedge ratio*. It is sometimes also called the *price sensitivity hedge ratio*.[5] Using it has the effect of making the duration of the entire position zero.

When the hedging instrument is a Treasury bond futures contract, the hedger must base D_F on an assumption that one particular bond will be delivered. This means that the hedger must estimate which of the available bonds is likely to be cheapest to deliver at the time the hedge is put in place. If, subsequently, the interest rate environment changes so that it looks as though a different bond will be cheapest to deliver, then the hedge has to be adjusted and as a result its performance may be worse than anticipated.

When hedges are constructed using interest rate futures, it is important to bear in mind that interest rates and futures prices move in opposite directions. When interest rates go up, an interest rate futures price goes down. When interest rates go down, the reverse happens, and the interest rate futures price goes up. Thus, a company in a position to lose money if interest rates drop should hedge by taking a long futures position. Similarly, a company in a position to lose money if interest rates rise should hedge by taking a short futures position.

The hedger tries to choose the futures contract so that the duration of the underlying asset is as close as possible to the duration of the asset being hedged. Eurodollar futures tend to be used for exposures to short-term

[5] For a more detailed discussion of Equation (9.5), see R.J. Rendleman, "Duration-Based Hedging with Treasury Bond Futures," *Journal of Fixed Income* 9, 1 (June 1999): 84–91.

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interest rates, whereas ultra T-bond, Treasury bond, and Treasury note futures contracts are used for exposures to longer-term rates.

Example 9.6

It is August 2 and a fund manager with $10 million invested in government bonds is concerned that interest rates are expected to be highly volatile over the next 3 months. The fund manager decides to use the December T-bond futures contract to hedge the value of the portfolio. The current futures price is 93-02, or 93.0625. Because each contract is for the delivery of $100,000 face value of bonds, the futures contract price is $93,062.50.

Suppose that the duration of the bond portfolio in 3 months will be 6.80 years. The cheapest-to-deliver bond in the T-bond contract is expected to be a 20-year 12% per annum coupon bond. The yield on this bond is currently 8.80% per annum, and the duration will be 9.20 years at maturity of the futures contract.

The fund manager requires a short position in T-bond futures to hedge the bond portfolio. If interest rates go up, a gain will be made on the short futures position, but a loss will be made on the bond portfolio. If interest rates decrease, a loss will be made on the short position, but there will be a gain on the bond portfolio. The number of bond futures contracts that should be shorted can be calculated from Equation (9.5) as

$$\frac{10{,}000{,}000}{93{,}062.50} \times \frac{6.80}{9.20} = 79.42$$

To the nearest whole number, the portfolio manager should short 79 contracts.

HEDGING PORTFOLIOS OF ASSETS AND LIABILITIES

Financial institutions sometimes attempt to hedge themselves against interest rate risk by ensuring that the average duration of their assets equals the average duration of their liabilities. (The liabilities can be regarded as short positions in bonds.) This strategy is known as *duration matching* or *portfolio immunization*. When implemented, it ensures that a small parallel shift in interest rates will have little effect on the value of the portfolio of assets and liabilities. The gain (loss) on the assets should offset the loss (gain) on the liabilities.

BOX 9-3 Asset–Liability Management by Banks

The asset–liability management (ALM) committees of banks now monitor their exposure to interest rates very carefully. Matching the durations of assets and liabilities is sometimes a first step, but this does not protect a bank against nonparallel shifts in the yield curve. A popular approach is known as *GAP management*. This involves dividing the zero-coupon yield curve into segments, known as *buckets*. The first bucket might be 0 to 1 month, the second 1 to 3 months, and so on. The ALM committee then investigates the effect on the value of the bank's portfolio of the zero rates corresponding to one bucket changing while those corresponding to all other buckets stay the same.

If there is a mismatch, corrective action is usually taken. This can involve changing deposit and lending rates in the way described in Chapter 7. Alternatively, tools such as swaps, FRAs, bond futures, Eurodollar futures, and other interest rate derivatives can be used.

Duration matching does not immunize a portfolio against nonparallel shifts in the zero curve. This is a weakness of the approach. In practice, short-term rates are usually more volatile than, and are not perfectly correlated with, long-term rates. Sometimes it even happens that short- and long-term rates move in opposite directions to each other. Duration matching is therefore only a first step and financial institutions have developed other tools to help them manage their interest rate exposure. See Box 9-3.

SUMMARY

Two very popular interest rate contracts are the Treasury bond and Eurodollar futures contracts that trade in the United States. In the Treasury bond futures contracts, the party with the short position has a number of interesting delivery options:

1. Delivery can be made on any day during the delivery month.
2. There are a number of alternative bonds that can be delivered.
3. On any day during the delivery month, the notice of intention to deliver at the 2:00 p.m. settlement price can be made later in the day.

These options all tend to reduce the futures price.

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The Eurodollar futures contract is a contract on the 3-month Eurodollar interest rate two days before the third Wednesday of the delivery month. Eurodollar futures are frequently used to estimate LIBOR forward rates for the purpose of constructing a LIBOR zero curve. When long-dated contracts are used in this way, it is important to make what is termed a convexity adjustment to allow for the difference between Eurodollar futures and FRAs.

The concept of duration is important in hedging interest rate risk. It enables a hedger to assess the sensitivity of a bond portfolio to small parallel shifts in the yield curve. It also enables the hedger to assess the sensitivity of an interest rate futures price to small changes in the yield curve. The number of futures contracts necessary to protect the bond portfolio against small parallel shifts in the yield curve can therefore be calculated.

The key assumption underlying duration-based hedging is that all interest rates change by the same amount. This means that only parallel shifts in the term structure are allowed for. In practice, short-term interest rates are generally more volatile than are long-term interest rates, and hedge performance is liable to be poor if the duration of the bond underlying the futures contract differs markedly from the duration of the asset being hedged.

Further Reading

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Swaps

10

Learning Objectives

After completing this reading you should be able to:

- Explain the mechanics of a plain vanilla interest rate swap and compute its cash flows.
- Explain how a plain vanilla interest rate swap can be used to transform an asset or a liability and calculate the resulting cash flows.
- Explain the role of financial intermediaries in the swaps market.
- Describe the role of the confirmation in a swap transaction.
- Describe the comparative advantage argument for the existence of interest rate swaps, and evaluate some of the criticisms of this argument.
- Explain how the discount rates in a plain vanilla interest rate swap are computed.
- Calculate the value of a plain vanilla interest rate swap based on two simultaneous bond positions.
- Calculate the value of a plain vanilla interest rate swap from a sequence of forward rate agreements (FRAs).
- Explain the mechanics of a currency swap and compute its cash flows.
- Explain how a currency swap can be used to transform an asset or liability and calculate the resulting cash flows.
- Calculate the value of a currency swap based on two simultaneous bond positions.
- Calculate the value of a currency swap based on a sequence of FRAs.
- Describe the credit risk exposure in a swap position.
- Identify and describe other types of swaps, including commodity, volatility, and exotic swaps.

Excerpt is Chapter 7 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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The birth of the over-the-counter swap market can be traced to a currency swap negotiated between IBM and the World Bank in 1981. The World Bank had borrowings denominated in US dollars while IBM had borrowings denominated in German deutsche marks and Swiss francs. The World Bank (which was restricted in the deutsche mark and Swiss franc borrowing it could do directly) agreed to make interest payments on IBM's borrowings while IBM in return agreed to make interest payments on the World Bank's borrowings.

Since that first transaction in 1981, the swap market has seen phenomenal growth. Swaps now occupy a position of central importance in over-the-counter derivatives markets. The statistics produced by the Bank for International Settlements show that about 58.5% of all over-the-counter derivatives are interest rate swaps and a further 4% are currency swaps. Most of this chapter is devoted to discussing these two types of swap. Other swaps are briefly reviewed at the end of the chapter.

A swap is an over-the-counter agreement between two companies to exchange cash flows in the future. The agreement defines the dates when the cash flows are to be paid and the way in which they are to be calculated. Usually the calculation of the cash flows involves the future value of an interest rate, an exchange rate, or other market variable.

A forward contract can be viewed as a simple example of a swap. Suppose it is March 1, 2016, and a company enters into a forward contract to buy 100 ounces of gold for $1,500 per ounce in 1 year. The company can sell the gold in 1 year as soon as it is received. The forward contract is therefore equivalent to a swap where the company agrees that it will pay $150,000 and receive 100*S* on March 1, 2017, where *S* is the market price of 1 ounce of gold on that date. However, whereas a forward contract is equivalent to the exchange of cash flows on just one future date, swaps typically lead to cash flow exchanges on several future dates.

The most popular (plain vanilla) interest rate swap is one where LIBOR is exchanged for a fixed rate of interest. When valuing swaps, we require a "risk-free" discount rate for cash flows. As mentioned in Chapter 7, LIBOR has traditionally been used as a proxy for the "risk-free" discount rate. As it happens, this greatly simplifies valuation of plain vanilla interest rate swaps because the discount rate is then the same as the reference interest rate in the swap. Since the 2008 credit crisis, other risk-free discount rates have been used, particularly for collateralized transactions. In this chapter, we assume that LIBOR is used as the risk-free discount rate.

MECHANICS OF INTEREST RATE SWAPS

In an interest rate swap, one company agrees to pay to another company cash flows equal to interest at a predetermined fixed rate on a notional principal for a predetermined number of years. In return, it receives interest at a floating rate on the same notional principal for the same period of time from the other company.

LIBOR

The floating rate in most interest rate swap agreements is the London Interbank Offered Rate (LIBOR). We introduced this in Chapter 7. It is the rate of interest at which a bank with a AA credit rating is able to borrow from other banks.

Just as prime is often the reference rate of interest for floating-rate loans in the domestic financial market, LIBOR is a reference rate of interest for loans in international financial markets. To understand how it is used, consider a 5-year bond with a rate of interest specified as 6-month LIBOR plus 0.5% per annum. The life of the bond is divided into 10 periods, each 6 months in length. For each period, the rate of interest is set at 0.5% per annum above the 6-month LIBOR rate at the beginning of the period. Interest is paid at the end of the period.

We will refer to a swap where LIBOR is exchanged for a fixed rate of interest as a "LIBOR-for-fixed" swap.

Illustration

Consider a hypothetical 3-year swap initiated on March 5, 2014, between Microsoft and Intel. We suppose Microsoft agrees to pay Intel an interest rate of 5% per annum on a principal of $100 million, and in return Intel agrees to pay Microsoft the 6-month LIBOR rate on the same principal. Microsoft is the *fixed-rate payer*; Intel is the *floating-rate payer*. We assume the agreement specifies that payments are to be exchanged every 6 months and that the 5% interest rate is quoted with semiannual compounding. This swap is represented diagrammatically in Figure 10-1.

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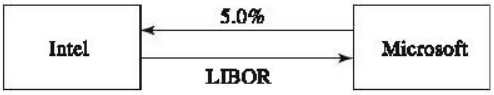

FIGURE 10-1 Interest rate swap between Microsoft and Intel.

The first exchange of payments would take place on September 5, 2014, 6 months after the initiation of the agreement. Microsoft would pay Intel $2.5 million. This is the interest on the $100 million principal for 6 months at 5%. Intel would pay Microsoft interest on the $100 million principal at the 6-month LIBOR rate prevailing 6 months prior to September 5, 2014—that is, on March 5, 2014. Suppose that the 6-month LIBOR rate on March 5, 2014, is 4.2%. Intel pays Microsoft 0.5 × 0.042 × $100 = $2.1 million.[1] Note that there is no uncertainty about this first exchange of payments because it is determined by the LIBOR rate at the time the swap begins.

The second exchange of payments would take place on March 5, 2015, a year after the initiation of the agreement. Microsoft would pay $2.5 million to Intel. Intel would pay interest on the $100 million principal to Microsoft at the 6-month LIBOR rate prevailing 6 months prior to March 5, 2015—that is, on September 5, 2014. Suppose that the 6-month LIBOR rate on September 5, 2014, proves to be 4.8%. Intel pays 0.5 × 0.048 × $100 = $2.4 million to Microsoft.

In total, there are six exchanges of payment on the swap. The fixed payments are always $2.5 million. The floating-rate payments on a payment date are calculated using the 6-month LIBOR rate prevailing 6 months before the payment date. An interest rate swap is generally structured so that one side remits the difference between the two payments to the other side. In our example, Microsoft would pay Intel $0.4 million (= $2.5 million − $2.1 million) on September 5, 2014, and $0.1 million (= $2.5 million − $2.4 million) on March 5, 2015.

[1] The calculations here are simplified in that they ignore day count conventions. This point is discussed in more detail later in the chapter.

Table 10-1 provides a complete example of the payments made under the swap for one particular set of 6-month LIBOR rates. The table shows the swap cash flows from the perspective of Microsoft. Note that the $100 million principal is used only for the calculation of interest payments. The principal itself is not exchanged. For this reason it is termed the *notional principal*, or just the *notional*.

If the notional principal were exchanged at the end of the life of the swap, the nature of the deal would not be changed in any way. The notional principal is the same for both the fixed and floating payments. Exchanging $100 million for $100 million at the end of the life of the swap is a transaction that would have no financial value to either Microsoft or Intel. Table 10-2 shows the cash flows in Table 10-1 with a final exchange of principal added in. This provides an interesting way of viewing the swap. The cash flows in the third column of this table are the cash flows from a long position in a floating-rate bond. The cash flows in the fourth column of the table are the cash flows from a short position in a fixed-rate bond. The table shows that the swap can be regarded as the exchange of a fixed-rate bond for a floating-rate bond. Microsoft, whose position is described by Table 10-2, is long a floating-rate bond and short a fixed-rate bond. Intel is long a fixed-rate bond and short a floating-rate bond.

This characterization of the cash flows in the swap helps to explain why the floating rate in the swap is set 6 months before it is paid. On a floating-rate bond,

TABLE 10-1 Cash Flows (millions of dollars) to Microsoft in a $100 Million 3-Year Interest Rate Swap When a Fixed Rate of 5% Is Paid and LIBOR Is Received

Date	Six-Month LIBOR Rate (%)	Floating Cash Flow Received	Fixed Cash Flow Paid	Net Cash Flow
Mar. 5, 2014	4.20			
Sept. 5, 2014	4.80	+2.10	−2.50	−0.40
Mar. 5, 2015	5.30	+2.40	−2.50	−0.10
Sept. 5, 2015	5.50	+2.65	−2.50	+0.15
Mar. 5, 2016	5.60	+2.75	−2.50	+0.25
Sept. 5, 2016	5.90	+2.80	−2.50	+0.30
Mar. 5, 2017		+2.95	−2.50	+0.45

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TABLE 10-2 Cash Flows (millions of dollars) from Table 10-1 When There Is a Final Exchange of Principal

Date	Six-Month LIBOR Rate (%)	Floating Cash Flow Received	Fixed Cash Flow Paid	Net Cash Flow
Mar. 5, 2014	4.20			
Sept. 5, 2014	4.80	+2.10	−2.50	−0.40
Mar. 5, 2015	5.30	+2.40	−2.50	−0.10
Sept. 5, 2015	5.50	+2.65	−2.50	+0.15
Mar. 5, 2016	5.60	+2.75	−2.50	+0.25
Sept. 5, 2016	5.90	+2.80	−2.50	+0.30
Mar. 5, 2017		+102.95	−102.50	+0.45

interest is generally set at the beginning of the period to which it will apply and is paid at the end of the period. The calculation of the floating-rate payments in a "plain vanilla" interest rate swap, such as the one in Table 10-2, reflects this.

Using the Swap to Transform a Liability

For Microsoft, the swap could be used to transform a floating-rate loan into a fixed-rate loan. Suppose that Microsoft has arranged to borrow $100 million at LIBOR plus 10 basis points. (One basis point is one-hundredth of 1%, so the rate is LIBOR plus 0.1%.) After Microsoft has entered into the swap, it has the following three sets of cash flows:

1. It pays LIBOR plus 0.1% to its outside lenders.
2. It receives LIBOR under the terms of the swap.
3. It pays 5% under the terms of the swap.

These three sets of cash flows net out to an interest rate payment of 5.1%. Thus, for Microsoft, the swap could have the effect of transforming borrowings at a floating rate of LIBOR plus 10 basis points into borrowings at a fixed rate of 5.1%.

For Intel, the swap could have the effect of transforming a fixed-rate loan into a floating-rate loan. Suppose that Intel has a 3-year $100 million loan outstanding on which it pays 5.2%. After it has entered into the swap, it has the following three sets of cash flows:

1. It pays 5.2% to its outside lenders.
2. It pays LIBOR under the terms of the swap.
3. It receives 5% under the terms of the swap.

These three sets of cash flows net out to an interest rate payment of LIBOR plus 0.2% (or LIBOR plus 20 basis points). Thus, for Intel, the swap could have the effect of transforming borrowings at a fixed rate of 5.2% into borrowings at a floating rate of LIBOR plus 20 basis points. These potential uses of the swap by Intel and Microsoft are illustrated in Figure 10-2.

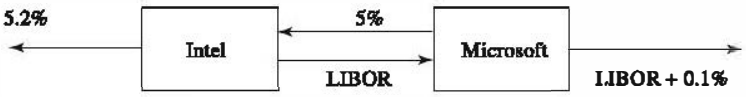

FIGURE 10-2 Microsoft and Intel use the swap to transform a liability.

Using the Swap to Transform an Asset

Swaps can also be used to transform the nature of an asset. Consider Microsoft in our example. The swap could have the effect of transforming an asset earning a fixed rate of interest into an asset earning a floating rate of interest. Suppose that Microsoft owns $100 million in bonds that will provide interest at 4.7% per annum over the next 3 years. After Microsoft has entered into the swap, it has the following three sets of cash flows:

1. It receives 4.7% on the bonds.
2. It receives LIBOR under the terms of the swap.
3. It pays 5% under the terms of the swap.

These three sets of cash flows net out to an interest rate inflow of LIBOR minus 30 basis points. Thus, one possible use of the swap for Microsoft is to transform an asset earning 4.7% into an asset earning LIBOR minus 30 basis points.

Next, consider Intel. The swap could have the effect of transforming an asset earning a floating rate of interest into an asset earning a fixed rate of interest. Suppose that Intel has an investment of $100 million that yields LIBOR minus 20 basis points. After it has

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entered into the swap, it has the following three sets of cash flows:

1. It receives LIBOR minus 20 basis points on its investment.
2. It pays LIBOR under the terms of the swap.
3. It receives 5% under the terms of the swap.

These three sets of cash flows net out to an interest rate inflow of 4.8%. Thus, one possible use of the swap for Intel is to transform an asset earning LIBOR minus 20 basis points into an asset earning 4.8%. These potential uses of the swap by Intel and Microsoft are illustrated in Figure 10-3.

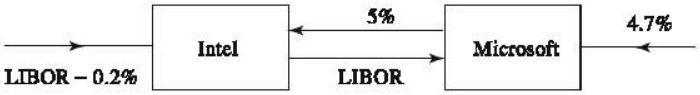

FIGURE 10-3 Microsoft and Intel use the swap to transform an asset.

FIGURE 10-4 Interest rate swap from Figure 10-2 when financial institution is involved.

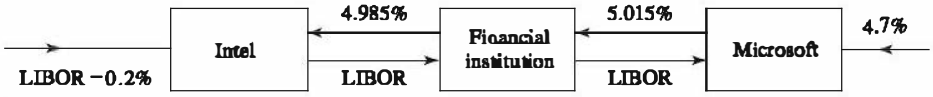

FIGURE 10-5 Interest rate swap from Figure 10-3 when financial institution is involved.

Role of Financial Intermediary

Usually two nonfinancial companies such as Intel and Microsoft do not get in touch directly to arrange a swap in the way indicated in Figures 10-2 and 10-3. They each deal with a bank or other financial institution. "Plain vanilla" LIBOR-for-fixed swaps on US interest rates are usually structured so that the financial institution earns about 3 or 4 basis points (0.03% or 0.04%) on a pair of offsetting transactions.

Figure 10-4 shows what the role of the financial institution might be in the situation in Figure 10-2. The financial institution enters into two offsetting swap transactions with Intel and Microsoft. Assuming that both companies honor their obligations, the financial institution is certain to make a profit of 0.03% (3 basis points) per year multiplied by the notional principal of $100 million. This amounts to $30,000 per year for the 3-year period. Microsoft ends up borrowing at 5.115% (instead of 5.1%, as in Figure 10-2), and Intel ends up borrowing at LIBOR plus 21.5 basis points (instead of at LIBOR plus 20 basis points, as in Figure 10-2).

Figure 10-5 illustrates the role of the financial institution in the situation in Figure 10-3. The swap is the same as before and the financial institution is certain to make a profit of 3 basis points if neither company defaults. Microsoft ends up earning LIBOR minus 31.5 basis points (instead of LIBOR minus 30 basis points, as in Figure 10-3), and Intel ends up earning 4.785% (instead of 4.8%, as in Figure 10-3).

Note that in each case the financial institution has entered into two separate transactions: one with Intel and the other with Microsoft. In most instances, Intel will not even know that the financial institution has entered into an offsetting swap with Microsoft, and vice versa. If one of the companies defaults, the financial institution still has to honor its agreement with the other company. The 3-basis-point spread earned by the financial institution is partly to compensate it for the risk that one of the two companies will default on the swap payments.

Market Makers

In practice, it is unlikely that two companies will contact a financial institution at the same time and want to take opposite positions in exactly the same swap. For this reason, many large financial institutions act as market makers for swaps. This means that they are prepared to enter into a swap without having an offsetting swap with another counterparty.[2] Market makers must carefully quantify and hedge the risks they are taking. Bonds, forward rate agreements, and interest rate futures are examples of the instruments that can be used for hedging by swap market makers. Table 10-3 shows quotes for plain vanilla US

[2] This is sometimes referred to as *warehousing* swaps.

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TABLE 10-3 Bid and Offer Fixed Rates in the Swap Market and Swap Rates (percent per annum)

Maturity (years)	Bid	Offer	Swap Rate
2	6.03	6.06	6.045
3	6.21	6.24	6.225
4	6.35	6.39	6.370
5	6.47	6.51	6.490
7	6.65	6.68	6.665
10	6.83	6.87	6.850

dollar swaps that might be posted by a market maker.[3] As mentioned earlier, the bid–offer spread is 3 to 4 basis points. The average of the bid and offer fixed rates is known as the *swap rate*. This is shown in the final column of Table 10-3.

Consider a new swap where the fixed rate equals the current swap rate. We can reasonably assume that the value of this swap is zero. (Why else would a market maker choose bid–offer quotes centered on the swap rate?) In Table 10-2 we saw that a swap can be characterized as the difference between a fixed-rate bond and a floating-rate bond. Define:

B_{fix}: Value of fixed-rate bond underlying the swap we are considering

B_{fl}: Value of floating-rate bond underlying the swap we are considering

Since the swap is worth zero, it follows that

$$B_{fix} = B_{fl} \tag{10.1}$$

We will use this result later in the chapter when discussing the determination of the LIBOR/swap zero curve.

DAY COUNT ISSUES

We discussed day count conventions in Chapter 9. The day count conventions affect payments on a swap, and some of the numbers calculated in the examples we have given do not exactly reflect these day count conventions. Consider, for example, the 6-month LIBOR payments in Table 10-1. Because it is a US money market rate, 6-month LIBOR is quoted on an actual/360 basis. The first floating payment in Table 10-1, based on the LIBOR rate of 4.2%, is shown as $2.10 million. Because there are 184 days between March 5, 2014, and September 5, 2014, it should be

$$100 \times 0.042 \times \frac{184}{360} = \$2.1467 \text{ million}$$

In general, a LIBOR-based floating-rate cash flow on a swap payment date is calculated as $LRn/360$, where L is the principal, R is the relevant LIBOR rate, and n is the number of days since the last payment date.

The fixed rate that is paid in a swap transaction is similarly quoted with a particular day count basis being specified. As a result, the fixed payments may not be exactly equal on each payment date. The fixed rate is usually quoted as actual/365 or 30/360. It is not therefore directly comparable with LIBOR because it applies to a full year. To make the rates approximately comparable, either the 6-month LIBOR rate must be multiplied by 365/360 or the fixed rate must be multiplied by 360/365.

For clarity of exposition, we will ignore day count issues in the calculations in the rest of this chapter.

CONFIRMATIONS

A *confirmation* is the legal agreement underlying a swap and is signed by representatives of the two parties. The drafting of confirmations has been facilitated by the work of the International Swaps and Derivatives Association (ISDA; www.isda.org) in New York. This organization has produced a number of Master Agreements that consist of clauses defining in some detail the terminology used in swap agreements, what happens in the event of default by either side, and so on. Master Agreements cover all outstanding transactions between two parties. In Box 10-1, we show a possible extract from the confirmation for the swap shown in Figure 10-4 between Microsoft and a financial institution (assumed here to be Goldman Sachs). The full confirmation might state that the provisions of an ISDA Master Agreement apply.

The confirmation specifies that the following business day convention is to be used and that the US calendar

[3] The standard swap in the United States is one where fixed payments made every 6 months are exchanged for floating LIBOR payments made every 3 months. In Table 10-1 we assumed that fixed and floating payments are exchanged every 6 months.

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BOX 10-1 Extract from Hypothetical Swap Confirmation

Trade date:	27-February-2014
Effective date:	5-March-2014
Business day convention (all dates):	Following business day
Holiday calendar:	US
Termination date:	5-March-2017
Fixed amounts	
Fixed-rate payer:	Microsoft
Fixed-rate notional principal:	USD 100 million
Fixed rate:	5.015% per annum
Fixed-rate day count convention:	Actual/365
Fixed-rate payment dates:	Each 5-March and 5-September, commencing 5-September-2014, up to and including 5-March-2017
Floating amounts	
Floating-rate payer:	Goldman Sachs
Floating-rate notional principal:	USD 100 million
Floating rate:	USD 6-month LIBOR
Floating-rate day count convention:	Actual/360
Floating-rate payment dates:	Each 5-March and 5-September, commencing 5-September-2014, up to and including 5-March-2017

determines which days are business days and which days are holidays. This means that, if a payment date falls on a weekend or a US holiday, the payment is made on the next business day.[4] March 5, 2016, is a Saturday. The payment scheduled for that day will therefore take place on March 7, 2016.

[4] Another business day convention that is sometimes specified is the *modified following* business day convention, which is the same as the following business day convention except that, when the next business day falls in a different month from the specified day, the payment is made on the immediately preceding business day. *Preceding* and *modified preceding* business day conventions are defined analogously.

THE COMPARATIVE-ADVANTAGE ARGUMENT

An explanation commonly put forward to explain the popularity of swaps concerns comparative advantage. Consider the use of an interest rate swap to transform a liability. Some companies, it is argued, have a comparative advantage when borrowing in fixed-rate markets, whereas other companies have a comparative advantage when borrowing in floating-rate markets. To obtain a new loan, it makes sense for a company to go to the market where it has a comparative advantage. As a result, the company may borrow fixed when it wants floating, or borrow floating when it wants fixed. The swap is used to transform a fixed-rate loan into a floating-rate loan, and vice versa.

Suppose that two companies, AAACorp and BBBCorp, both wish to borrow $10 million for 5 years and have been offered the rates shown in Table 10-4. AAACorp has a AAA credit rating; BBBCorp has a BBB credit rating.[5] We assume that BBBCorp wants to borrow at a fixed rate of interest, whereas AAACorp wants to borrow at a floating rate of interest linked to 6-month LIBOR. Because it has a worse credit rating than AAACorp, BBBCorp pays a higher rate of interest than AAACorp in both fixed and floating markets.

A key feature of the rates offered to AAACorp and BBBCorp is that the difference between the two fixed rates is greater than the difference between the two floating rates. BBBCorp pays 1.2% more than AAACorp in fixed-rate markets and only 0.7% more than AAACorp in floating-rate markets. BBBCorp appears to have a comparative advantage in floating-rate markets, whereas AAACorp appears to have a comparative advantage in

TABLE 10-4 Borrowing Rates That Provide a Basis for the Comparative-Advantage Argument

	Fixed	Floating
AAACorp	4.0%	6-month LIBOR − 0.1%
BBBCorp	5.2%	6-month LIBOR + 0.6%

[5] The credit ratings assigned to companies by S&P and Fitch (in order of decreasing creditworthiness) are AAA, AA, A, BBB, BB, B, CCC, CC, and C. The corresponding ratings assigned by Moody's are Aaa, Aa, A, Baa, Ba, B, Caa, Ca, and C, respectively.

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fixed-rate markets.[6] It is this apparent anomaly that can lead to a swap being negotiated. AAACorp borrows fixed-rate funds at 4% per annum. BBBCorp borrows floating-rate funds at LIBOR plus 0.6% per annum. They then enter into a swap agreement to ensure that AAACorp ends up with floating-rate funds and BBBCorp ends up with fixed-rate funds.

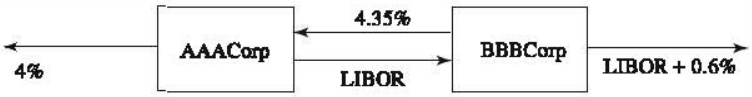

FIGURE 10-6 Swap agreement between AAACorp and BBBCorp when rates in Table 10-4 apply.

FIGURE 10-7 Swap agreement between AAACorp and BBBCorp when rates in Table 10-4 apply and a financial intermediary is involved.

To understand how this swap might work, we first assume that AAACorp and BBBCorp get in touch with each other directly. The sort of swap they might negotiate is shown in Figure 10-6. This is similar to our example in Figure 10-2. AAACorp agrees to pay BBBCorp interest at 6-month LIBOR on $10 million. In return, BBBCorp agrees to pay AAACorp interest at a fixed rate of 4.35% per annum on $10 million.

AAACorp has three sets of interest rate cash flows:

1. It pays 4% per annum to outside lenders.
2. It receives 4.35% per annum from BBBCorp.
3. It pays LIBOR to BBBCorp.

The net effect of the three cash flows is that AAACorp pays LIBOR minus 0.35% per annum. This is 0.25% per annum less than it would pay if it went directly to floating-rate markets. BBBCorp also has three sets of interest rate cash flows:

1. It pays LIBOR + 0.6% per annum to outside lenders.
2. It receives LIBOR from AAACorp.
3. It pays 4.35% per annum to AAACorp.

The net effect of the three cash flows is that BBBCorp pays 4.95% per annum. This is 0.25% per annum less than it would pay if it went directly to fixed-rate markets.

In this example, the swap has been structured so that the net gain to both sides is the same, 0.25%. This need not be the case. However, the total apparent gain from this type of interest rate swap arrangement is always $a - b$, where a is the difference between the interest rates facing the two companies in fixed-rate markets, and b is the difference between the interest rates facing the two companies in floating-rate markets. In this case, a = 1.2% and b = 0.7%, so that the total gain is 0.5%.

If AAACorp and BBBCorp did not deal directly with each other and used a financial institution, an arrangement such as that shown in Figure 10-7 might result. (This is similar to the example in Figure 10-4.) In this case, AAACorp ends up borrowing at LIBOR minus 0.33%, BBBCorp ends up borrowing at 4.97%, and the financial institution earns a spread of 4 basis points per year. The gain to AAACorp is 0.23%; the gain to BBBCorp is 0.23%; and the gain to the financial institution is 0.04%. The total gain to all three parties is 0.50% as before.

Criticism of the Argument

The comparative-advantage argument we have just outlined for explaining the attractiveness of interest rate swaps is open to question. Why in Table 10-4 should the spreads between the rates offered to AAACorp and BBBCorp be different in fixed and floating markets? Now that the interest rate swap market has been in existence for a long time, we might reasonably expect these types of differences to have been arbitraged away.

The reason that spread differentials appear to exist is due to the nature of the contracts available to companies in fixed and floating markets. The 4.0% and 5.2% rates available to AAACorp and BBBCorp in fixed-rate markets are 5-year rates (e.g., the rates at which the companies can issue 5-year fixed-rate bonds). The LIBOR − 0.1% and LIBOR + 0.6% rates available to AAACorp and BBBCorp in floating-rate markets are 6-month rates. In the floating-rate market, the lender usually has the opportunity to

[6] Note that BBBCorp's comparative advantage in floating-rate markets does not imply that BBBCorp pays less than AAACorp in this market. It means that the extra amount that BBBCorp pays over the amount paid by AAACorp is less in this market. One of my students summarized the situation as follows: "AAACorp pays more less in fixed-rate markets; BBBCorp pays less more in floating-rate markets."

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review the floating rates every 6 months. If the creditworthiness of AAACorp or BBBCorp has declined, the lender has the option of increasing the spread over LIBOR that is charged. In extreme circumstances, the lender can refuse to roll over the loan at all. The providers of fixed-rate financing do not have the option to change the terms of the loan in this way.[7]

The spreads between the rates offered to AAACorp and BBBCorp are a reflection of the extent to which BBBCorp is more likely than AAACorp to default. During the next 6 months, there is very little chance that either AAACorp or BBBCorp will default. As we look further ahead, the probability of a default by a company with a relatively low credit rating (such as BBBCorp) is liable to increase faster than the probability of a default by a company with a relatively high credit rating (such as AAACorp). This is why the spread between the 5-year rates is greater than the spread between the 6-month rates.

After negotiating a floating-rate loan at LIBOR + 0.6% and entering into the swap shown in Figure 10-7, BBBCorp appears to obtain a fixed-rate loan at 4.97%. The arguments just presented show that this is not really the case. In practice, the rate paid is 4.97% only if BBBCorp can continue to borrow floating-rate funds at a spread of 0.6% over LIBOR. If, for example, the creditworthiness of BBBCorp declines so that the floating-rate loan is rolled over at LIBOR + 1.6%, the rate paid by BBBCorp increases to 5.97%. The market expects that BBBCorp's spread over 6-month LIBOR will on average rise during the swap's life. BBBCorp's expected average borrowing rate when it enters into the swap is therefore greater than 4.97%.

The swap in Figure 10-7 locks in LIBOR − 0.33% for AAACorp for the next 5 years, not just for the next 6 months. This appears to be a good deal for AAACorp. The downside is that it is bearing the risk of a default on the swap by the financial institution. If it borrowed floating-rate funds in the usual way, it would not be bearing this risk.

THE NATURE OF SWAP RATES

At this stage it is appropriate to examine the nature of swap rates and the relationship between swap and LIBOR markets. We explained in Chapter 7 that LIBOR is the rate of interest at which AA-rated banks borrow for periods up to 12 months from other banks. Also, as indicated in Table 10-3, a swap rate is the average of (a) the fixed rate that a swap market maker is prepared to pay in exchange for receiving LIBOR (its bid rate) and (b) the fixed rate that it is prepared to receive in return for paying LIBOR (its offer rate).

Like LIBOR rates, swap rates are not risk-free lending rates. However, they are reasonably close to risk-free in normal market conditions. A financial institution can earn the 5-year swap rate on a certain principal by doing the following:

1. Lend the principal for the first 6 months to a AA borrower and then relend it for successive 6-month periods to other AA borrowers; and
2. Enter into a swap to exchange the LIBOR income for the 5-year swap rate.

This shows that the 5-year swap rate is an interest rate with a credit risk corresponding to the situation where 10 consecutive 6-month LIBOR loans to AA companies are made. Similarly the 7-year swap rate is an interest rate with a credit risk corresponding to the situation where 14 consecutive 6-month LIBOR loans to AA companies are made. Swap rates of other maturities can be interpreted analogously.

Note that 5-year swap rates are less than 5-year AA borrowing rates. It is much more attractive to lend money for successive 6-month periods to borrowers who are always AA at the beginning of the periods than to lend it to one borrower for the whole 5 years when all we can be sure of is that the borrower is AA at the beginning of the 5 years.

In discussing the above points, Collin-Dufesne and Solnik refer to swap rates as "continually refreshed" LIBOR rates.[8]

DETERMINING LIBOR/SWAP ZERO RATES

One problem with LIBOR rates is that direct observations are possible only for maturities out to 12 months. As

[7] If the floating-rate loans are structured so that the spread over LIBOR is guaranteed in advance regardless of changes in credit rating, the spread differentials disappear.

[8] See P. Collin-Dufesne and B. Solnik, "On the Term Structure of Default Premia in the Swap and Libor Market," *Journal of Finance*, 56, 3 (June 2001).

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described in Chapter 9, one way of extending the LIBOR zero curve beyond 12 months is to use Eurodollar futures. Typically Eurodollar futures are used to produce a LIBOR zero curve out to 2 years—and sometimes out to as far as 5 years. Traders then use swap rates to extend the LIBOR zero curve further. The resulting zero curve is sometimes referred to as the LIBOR zero curve and sometimes as the swap zero curve. To avoid any confusion, we will refer to it as the *LIBOR/swap zero curve*. We will now describe how swap rates are used in the determination of the LIBOR/swap zero curve.

The first point to note is that the value of a newly issued floating-rate bond that pays 6-month LIBOR is always equal to its principal value (or par value) when the LIBOR/swap zero curve is used for discounting.[9] The reason is that the bond provides a rate of interest of LIBOR, and LIBOR is the discount rate. The interest on the bond exactly matches the discount rate, and as a result the bond is fairly priced at par.

In Equation (10.1), we showed that for a newly issued swap where the fixed rate equals the swap rate, $B_{fix} = B_{fl}$. We have just argued that B_{fl} equals the notional principal. It follows that B_{fix} also equals the swap's notional principal. Swap rates therefore define a set of par yield bonds. For example, from Table 10-3, we can deduce that the 2-year LIBOR/swap par yield is 6.045%, the 3-year LIBOR/swap par yield is 6.225%, and so on.[10]

Chapter 7 showed how the bootstrap method can be used to determine the Treasury zero curve from Treasury bond prices. It can be used with swap rates in a similar way to extend the LIBOR/swap zero curve.

Example 10.1

Suppose that the 6-month, 12-month, and 18-month LIBOR/swap zero rates have been determined as 4%, 4.5%, and 4.8% with continuous compounding and that the 2-year swap rate (for a swap where payments are made semiannually) is 5%. This 5% swap rate means that a bond with a principal of $100 and a semiannual coupon of 5% per annum sells for par. It follows that, if R is the 2-year zero rate, then

$$2.5e^{-0.04\times0.5} + 2.5e^{-0.045\times1.0} + 2.5e^{-0.048\times1.5} + 102.5e^{-2R} = 100$$

Solving this, we obtain $R = 4.953\%$. (Note that this calculation does not take day count conventions and holiday calendars into account. See earlier.)

VALUATION OF INTEREST RATE SWAPS

We now move on to discuss the valuation of interest rate swaps. An interest rate swap is worth close to zero when it is first initiated. After it has been in existence for some time, its value may be positive or negative. There are two valuation approaches when LIBOR/swap rates are used as discount rates. The first regards the swap as the difference between two bonds; the second regards it as a portfolio of FRAs. DerivaGem 3.00 can be used to value the swap with either LIBOR or OIS discounting.

Valuation In Terms of Bond Prices

Principal payments are not exchanged in an interest rate swap. However, as illustrated in Table 10-2, we can assume that principal payments are both received and paid at the end of the swap without changing its value. By doing this, we find that, from the point of view of the floating-rate payer, a swap can be regarded as a long position in a fixed-rate bond and a short position in a floating-rate bond, so that

$$V_{swap} = B_{fix} - B_{fl}$$

where V_{swap} is the value of the swap, B_{fl} is the value of the floating-rate bond (corresponding to payments that are made), and B_{fix} is the value of the fixed-rate bond (corresponding to payments that are received). Similarly, from the point of view of the fixed-rate payer, a swap is a long position in a floating-rate bond and a short position in a fixed-rate bond, so that the value of the swap is

$$V_{swap} = B_{fl} - B_{fix}$$

The value of the fixed rate bond, B_{fix}, can be determined as described in Chapter 7. To value the floating-rate bond, we note that the bond is worth the notional principal immediately after a payment. This is because at this time the bond is a "fair deal" where the borrower pays LIBOR for each subsequent accrual period.

[9] The same is of course true of a newly issued bond that pays 1-month, 3-month, or 12-month LIBOR.

[10] Analysts frequently interpolate between swap rates before calculating the zero curve, so that they have swap rates for maturities at 6-month intervals. For example, for the data in Table 10-3 the 2.5-year swap rate would be assumed to be 6.135%; the 7.5-year swap rate would be assumed to be 6.696%; and so on.

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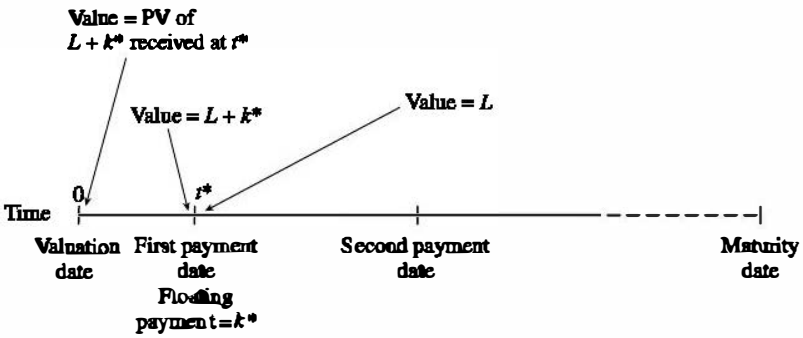

FIGURE 10-8 Valuation of floating-rate bond when bond principal is L and next payment is k^* at t^*.

Suppose that the notional principal is L, the next exchange of payments is at time t^*, and the floating payment that will be made at time t^* (which was determined at the last payment date) is k^*. Immediately after the payment $B_{fl} = L$ as just explained. It follows that immediately before the payment $B_{fl} = L + k^*$. The floating-rate bond can therefore be regarded as an instrument providing a single cash flow of $L + k^*$ at time t^*. Discounting this, the value of the floating-rate bond today is $(L + k^*)e^{-r^*t^*}$, where r^* is the LIBOR/swap zero rate for a maturity of t^*. This argument is illustrated in Figure 10-8.

Example 10.2

Suppose that some time ago a financial institution agreed to receive 6-month LIBOR and pay 3% per annum (with semiannual compounding) on a notional principal of \$100 million. The swap has a remaining life of 1.25 years. The LIBOR rates with continuous compounding for 3-month, 9-month, and 15-month maturities are 2.8%, 3.2%, and 3.4%, respectively. The 6-month LIBOR rate at the last payment date was 2.9% (with semiannual compounding).

The calculations for valuing the swap in terms of bonds are summarized in Table 10-5. The fixed-rate bond has cash flows of 1.5, 1.5, and 101.5 on the three payment dates. The discount factors for these cash flows are, respectively, $e^{-0.028\times0.25}$, $e^{-0.032\times0.75}$, and $e^{-0.034\times1.25}$ and are shown in the fourth column of Table 10-5. The table shows that the value of the fixed-rate bond (in millions of dollars) is 100.2306.

In this example, L = \$100 million, $k^* = 0.5 \times 0.029 \times 100$ = \$1.4500 million, and $t^* = 0.25$, so that the floating-rate bond can be valued as though it produces a cash flow of \$101.4500 million in 3 months. The table shows that the value of the floating bond (in millions of dollars) is $101.4500 \times 0.9930 = 100.7423$.

The value of the swap is the difference between the two bond prices:

$$V_{swap} = 100.7423 - 100.2306 = 0.5117$$

or +0.5117 million dollars.

If the financial institution had been in the opposite position of paying fixed and receiving floating, the value of the swap would be −\$0.5117 million. Note that these calculations do not take account of day count conventions and holiday calendars.

Valuation in Terms of FRAs

A swap can be characterized as a portfolio of forward rate agreements. Consider the swap between Microsoft and Intel in Figure 10-1. The swap is a 3-year deal entered into on March 5, 2014, with semiannual payments. The first exchange of payments is known at the time the swap is negotiated. The other five exchanges can be regarded as

TABLE 10-5 Valuing a Swap in Terms of Bonds (\$ millions). Here, B_{fix} is fixed-rate bond underlying the swap, and B_{fl} is floating-rate bond underlying the swap.

Time	B_{fix} Cash Flow	B_{fl} Cash Flow	Discount Factor	Present Value B_{fix} Cash Flow	Present Value B_{fl} Cash Flow
0.25	1.5	101.4500	0.9930	1.4895	100.7423
0.75	1.5		0.9763	1.4644	
1.25	101.5		0.9584	97.2766	
Total:				100.2306	100.7423

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TABLE 10-6 Valuing Swap in Terms of FRAs ($ millions). Floating cash flows are calculated by assuming that forward rates will be realized.

Time	Fixed Cash Flow	Floating Cash Flow	Net Cash Flow	Discount Factor	Present Value of Net Cash Flow
0.25	−1.5000	+1.4500	−0.0500	0.9930	−0.0497
0.75	−1.5000	+1.7145	+0.2145	0.9763	+0.2094
1.25	−1.5000	+1.8672	+0.3672	0.9584	+0.3519
Total:					+0.5117

FRAs. The exchange on March 5, 2015, is an FRA where interest at 5% is exchanged for interest at the 6-month rate observed in the market on September 5, 2014; the exchange on September 5, 2015, is an FRA where interest at 5% is exchanged for interest at the 6-month rate observed in the market on March 5, 2015; and so on.

As shown in Chapter 7, an FRA can be valued by assuming that forward interest rates are realized. Because it is nothing more than a portfolio of forward rate agreements, a plain vanilla interest rate swap can also be valued by making the assumption that forward interest rates are realized. The procedure is as follows:

1. Use the LIBOR/swap zero curve to calculate forward rates for each of the LIBOR rates that will determine swap cash flows.
2. Calculate swap cash flows on the assumption that the LIBOR rates will equal the forward rates.
3. Discount these swap cash flows (using the LIBOR/swap zero curve) to obtain the swap value.

Example 10.3

Consider again the situation in Example 10.2. Under the terms of the swap, a financial institution has agreed to receive 6-month LIBOR and pay 3% per annum (with semiannual compounding) on a notional principal of $100 million. The swap has a remaining life of 1.25 years. The LIBOR rates with continuous compounding for 3-month, 9-month, and 15-month maturities are 2.8%, 3.2%, and 3.4%, respectively. The 6-month LIBOR rate at the last payment date was 2.9% (with semiannual compounding).

The calculations are summarized in Table 10-6. The first row of the table shows the cash flows that will be exchanged in 3 months. These have already been determined. The fixed rate of 3% per year will lead to a cash outflow of 100 × 0.030 × 0.5 = $1.5 million. The floating rate of 2.9% (which was set 3 months ago) will lead to a cash inflow of 100 × 0.029 × 0.5 = $1.45 million. The second row of the table shows the cash flows that will be exchanged in 9 months assuming that forward rates are realized. The cash outflow is $1.5 million as before. To calculate the cash inflow, we must first calculate the forward rate corresponding to the period between 3 and 9 months. From Equation (7.5), this is

$$\frac{0.032 \times 0.75 - 0.028 \times 0.25}{0.5} = 0.034$$

or 3.4% with continuous compounding. From Equation (7.4), the forward rate becomes 3.429% with semiannual compounding. The cash inflow is therefore 100 × 0.03429 × 0.5 = $1.7145 million. The third row similarly shows the cash flows that will be exchanged in 15 months assuming that forward rates are realized. The discount factors for the three payment dates are, respectively,

$$e^{-0.028\times 0.25}, \quad e^{-0.032\times 0.75}, \quad e^{-0.034\times 1.25}$$

The present value of the exchange in three months is −$0.0497 million. The values of the FRAs corresponding to the exchanges in 9 months and 15 months are +$0.2094 and +$0.3519 million, respectively. The total value of the swap is +$0.5117 million. This is in agreement with the value we calculated in Example 10.2 by decomposing the swap into bonds.

TERM STRUCTURE EFFECTS

A swap is worth close to zero initially. This means that at the outset of a swap the sum of the values of the FRAs underlying the swap is close to zero. It does not mean that

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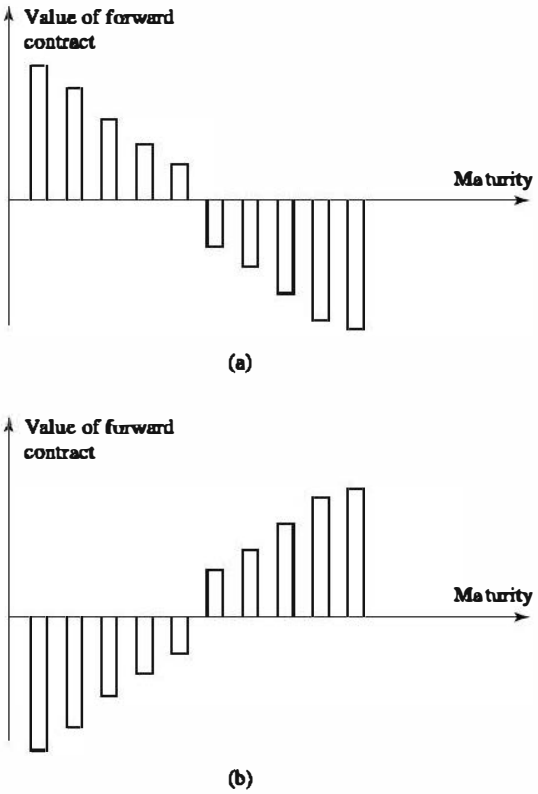

FIGURE 10-9 Valuing of forward rate agreements underlying a swap as a function of maturity. In (a) the term structure of interest rates is upward-sloping and we receive fixed, or it is downward-sloping and we receive floating; in (b) the term structure of interest rates is upward-sloping and we receive floating, or it is downward-sloping and we receive fixed.

the value of each individual FRA is close to zero. In general, some FRAs will have positive values whereas others have negative values.

Consider the FRAs underlying the swap between Microsoft and Intel in Figure 10-1:

Value of FRA to Microsoft > 0 when forward interest rate > 5.0%

Value of FRA to Microsoft = 0 when forward interest rate = 5.0%

Value of FRA to Microsoft < 0 when forward interest rate < 5.0%.

Suppose that the term structure of interest rates is upward-sloping at the time the swap is negotiated. This means that the forward interest rates increase as the maturity of the FRA increases. Since the sum of the values of the FRAs is close to zero, the forward interest rate must be less than 5.0% for the early payment dates and greater than 5.0% for the later payment dates. The value to Microsoft of the FRAs corresponding to early payment dates is therefore negative, whereas the value of the FRAs corresponding to later payment dates is positive. If the term structure of interest rates is downward-sloping at the time the swap is negotiated, the reverse is true. The impact of the shape of the term structure of interest rates on the values of the forward contracts underlying a swap is illustrated in Figure 10-9.

FIXED-FOR-FIXED CURRENCY SWAPS

Another popular type of swap is known as a *fixed-for-fixed currency swap*. This involves exchanging principal and interest payments at a fixed rate in one currency for principal and interest payments at a fixed rate in another currency.

A currency swap agreement requires the principal to be specified in each of the two currencies. The principal amounts are usually exchanged at the beginning and at the end of the life of the swap. Usually the principal amounts are chosen to be approximately equivalent using the exchange rate at the swap's initiation. When they are exchanged at the end of the life of the swap, their values may be quite different.

Illustration

Consider a hypothetical 5-year currency swap agreement between IBM and British Petroleum entered into on February 1, 2014. We suppose that IBM pays a fixed rate of interest of 5% in sterling and receives a fixed rate of interest of 6% in dollars from British Petroleum. Interest rate payments are made once a year and the principal amounts are $15 million and £10 million. This is termed a *fixed-for-fixed* currency swap because the interest rate in each currency is at a fixed rate. The swap is shown in Figure 10-10. Initially, the principal amounts flow in the opposite direction to the arrows in Figure 10-10. The interest payments during the life of the swap and the final principal payment flow in the same direction as the arrows. Thus, at the outset of the swap, IBM pays $15 million and receives £10 million. Each year during the life of the swap contract, IBM receives $0.90 million (= 6% of $15 million)

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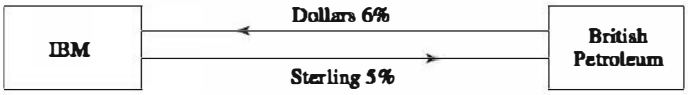

FIGURE 10-10 A currency swap.

TABLE 10-7 Cash Flows to IBM in Currency Swap

Date	Dollar Cash Flow (millions)	Sterling Cash Flow (millions)
February 1, 2014	−15.00	+10.00
February 1, 2015	+0.90	−0.50
February 1, 2016	+0.90	−0.50
February 1, 2017	+0.90	−0.50
February 1, 2018	+0.90	−0.50
February 1, 2019	+15.90	−10.50

and pays £0.50 million (= 5% of £10 million). At the end of the life of the swap, it pays a principal of £10 million and receives a principal of $15 million. These cash flows are shown in Table 10-7.

Use of a Currency Swap to Transform Liabilities and Assets

A swap such as the one just considered can be used to transform borrowings in one currency to borrowings in another. Suppose that IBM can issue $15 million of US-dollar-denominated bonds at 6% interest. The swap has the effect of transforming this transaction into one where IBM has borrowed £10 million at 5% interest. The initial exchange of principal converts the proceeds of the bond issue from US dollars to sterling. The subsequent exchanges in the swap have the effect of swapping the interest and principal payments from dollars to sterling.

The swap can also be used to transform the nature of assets. Suppose that IBM can invest £10 million in the UK to yield 5% per annum for the next 5 years, but feels that the US dollar will strengthen against sterling and prefers a US-dollar-denominated investment. The swap has the effect of transforming the UK investment into a $15 million investment in the US yielding 6%.

TABLE 10-8 Borrowing Rates Providing Basis for Currency Swap

	USD*	AUD*
General Electric	5.0%	7.6%
Qantas Airways	7.0%	8.0%

* Quoted rates have been adjusted to reflect the differential impact of taxes.

Comparative Advantage

Currency swaps can be motivated by comparative advantage. To illustrate this, we consider another hypothetical example. Suppose the 5-year fixed-rate borrowing costs to General Electric and Qantas Airways in US dollars (USD) and Australian dollars (AUD) are as shown in Table 10-8. The data in the table suggest that Australian rates are higher than USD interest rates, and also that General Electric is more creditworthy than Qantas Airways, because it is offered a more favorable rate of interest in both currencies. From the viewpoint of a swap trader, the interesting aspect of Table 10-8 is that the spreads between the rates paid by General Electric and Qantas Airways in the two markets are not the same. Qantas Airways pays 2% more than General Electric in the US dollar market and only 0.4% more than General Electric in the AUD market.

This situation is analogous to that in Table 10-4. General Electric has a comparative advantage in the USD market, whereas Qantas Airways has a comparative advantage in the AUD market. In Table 10-4, where a plain vanilla interest rate swap was considered, we argued that comparative advantages are largely illusory. Here we are comparing the rates offered in two different currencies, and it is more likely that the comparative advantages are genuine. One possible source of comparative advantage is tax. General Electric's position might be such that USD borrowings lead to lower taxes on its worldwide income than AUD borrowings. Qantas Airways' position might be the reverse. (Note that we assume that the interest rates shown in Table 10-8 have been adjusted to reflect these types of tax advantages.)

We suppose that General Electric wants to borrow 20 million AUD and Qantas Airways wants to borrow 18 million USD and that the current exchange rate (USD

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per AUD) is 0.9000. This creates a perfect situation for a currency swap. General Electric and Qantas Airways each borrow in the market where they have a comparative advantage; that is, General Electric borrows USD whereas Qantas Airways borrows AUD. They then use a currency swap to transform General Electric's loan into an AUD loan and Qantas Airways' loan into a USD loan.

As already mentioned, the difference between the USD interest rates is 2%, whereas the difference between the AUD interest rates is 0.4%. By analogy with the interest rate swap case, we expect the total gain to all parties to be 2.0 − 0.4 = 1.6% per annum.

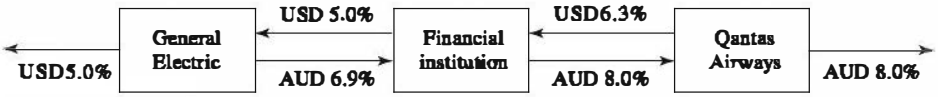

FIGURE 10-11 A currency swap motivated by comparative advantage.

FIGURE 10-12 Alternative arrangement for currency swap: Qantas Airways bears some foreign exchange risk.

FIGURE 10-13 Alternative arrangement for currency swap: General Electric bears some foreign exchange risk.

There are several ways in which the swap can be arranged. Figure 10-11 shows one way swaps might be entered into with a financial institution. General Electric borrows USD and Qantas Airways borrows AUD. The effect of the swap is to transform the USD interest rate of 5% per annum to an AUD interest rate of 6.9% per annum for General Electric. As a result, General Electric is 0.7% per annum better off than it would be if it went directly to AUD markets. Similarly, Qantas exchanges an AUD loan at 8% per annum for a USD loan at 6.3% per annum and ends up 0.7% per annum better off than it would be if it went directly to USD markets. The financial institution gains 1.3% per annum on its USD cash flows and loses 1.1% per annum on its AUD flows. If we ignore the difference between the two currencies, the financial institution makes a net gain of 0.2% per annum. As predicted, the total gain to all parties is 1.6% per annum.

Each year the financial institution makes a gain of USD 234,000 (= 1.3% of 18 million) and incurs a loss of AUD 220,000 (= 1.1% of 20 million). The financial institution can avoid any foreign exchange risk by buying AUD 220,000 per annum in the forward market for each year of the life of the swap, thus locking in a net gain in USD.

It is possible to redesign the swap so that the financial institution makes a 0.2% spread in USD. Figures 10-12 and 10-13 present two alternatives. These alternatives are unlikely to be used in practice because they do not lead to General Electric and Qantas being free of foreign exchange risk.[11] In Figure 10-12, Qantas bears some foreign exchange risk because it pays 1.1% per annum in AUD and pays 5.2% per annum in USD. In Figure 10-13, General Electric bears some foreign exchange risk because it receives 1.1% per annum in USD and pays 8% per annum in AUD.

VALUATION OF FIXED-FOR-FIXED CURRENCY SWAPS

Like interest rate swaps, fixed-for-fixed currency swaps can be decomposed into either the difference between two bonds or a portfolio of forward contracts.

Valuation In Terms of Bond Prices

If we define V_{swap} as the value in US dollars of an outstanding swap where dollars are received and a foreign currency is paid, then

$$V_{swap} = B_D - S_0 B_F$$

where B_F is the value, measured in the foreign currency, of the bond defined by the foreign cash flows on the swap

[11] Usually it makes sense for the financial institution to bear the foreign exchange risk, because it is in the best position to hedge the risk.

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and B_D is the value of the bond defined by the domestic cash flows on the swap, and S_0 is the spot exchange rate (expressed as number of dollars per unit of foreign currency). The value of a swap can therefore be determined from interest rates in the two currencies and the spot exchange rate.

Similarly, the value of a swap where the foreign currency is received and dollars are paid is

$$V_{swap} = S_0 B_F - B_D$$

Example 10.4

Suppose that the term structure of interest rates is flat in both Japan and the United States. The Japanese rate is 4% per annum and the US rate is 9% per annum (both with continuous compounding). Some time ago a financial institution has entered into a currency swap in which it receives 5% per annum in yen and pays 8% per annum in dollars once a year. The principals in the two currencies are $10 million and 1,200 million yen. The swap will last for another 3 years, and the current exchange rate is 110 yen = $1.

The calculations are summarized in Table 10-9. In this case, the cash flows from the dollar bond underlying the swap are as shown in the second column. The present value of the cash flows using the dollar discount rate of 9% are shown in the third column. The cash flows from the yen bond underlying the swap are shown in the fourth column of the table. The present value of the cash flows using the yen discount rate of 4% are shown in the final column of the table.

TABLE 10-9 Valuation of Currency Swap in Terms of Bonds (all amounts in millions)

Time	Cash Flows on Dollar Bond ($)	Present Value ($)	Cash Flows on Yen Bond (yen)	Present Value (yen)
1	0.8	0.7311	60	57.65
2	0.8	0.6682	60	55.39
3	0.8	0.6107	60	53.22
3	10.0	7.6338	1,200	1,064.30
Total:		9.6439		1,230.55

The value of the dollar bond, B_D, is 9.6439 million dollars. The value of the yen bond is 1230.55 million yen. The value of the swap in dollars is therefore

$$\frac{1{,}230.55}{110} - 9.6439 = 1.5430 \text{ million}$$

Valuation as Portfolio of Forward Contracts

Each exchange of payments in a fixed-for-fixed currency swap is a forward foreign exchange contract. In Chapter 8, forward foreign exchange contracts were valued by assuming that forward exchange rates are realized. The same assumption can therefore be made for a currency swap.

Example 10.5

Consider again the situation in Example 10.4. The term structure of interest rates is flat in both Japan and the United States. The Japanese rate is 4% per annum and the US rate is 9% per annum (both with continuous compounding). Some time ago a financial institution has entered into a currency swap in which it receives 5% per annum in yen and pays 8% per annum in dollars once a year. The principals in the two currencies are $10 million and 1,200 million yen. The swap will last for another 3 years, and the current exchange rate is 110 yen = $1.

The calculations are summarized in Table 10-10. The financial institution pays 0.08 × 10 = $0.8 million dollars and receives 1,200 × 0.05 = 60 million yen each year. In addition, the dollar principal of $10 million is paid and the yen principal of 1,200 is received at the end of year 3. The current spot rate is 0.009091 dollar per yen. In this case r = 9% and r_f = 4%, so that, from Equation (8.9), the 1-year forward rate is

$$0.009091e^{(0.09-0.04)\times 1} = 0.009557$$

The 2- and 3-year forward rates in Table 10-10 are calculated similarly. The forward contracts underlying the swap can be valued by assuming that the forward rates are realized. If the 1-year forward rate is realized, the yen cash flow in year 1 is worth 60 × 0.009557 = 0.5734 million dollars and the net cash flow at the end of year 1 is 0.5734 − 0.8 = −0.2266 million dollars. This has a present value of

$$-0.2266e^{-0.09\times 1} = -0.2071$$

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TABLE 10-10 Valuation of Currency Swap as a Portfolio of Forward Contracts (all amounts in millions)

Time	Dollar Cash Flow	Yen Cash Flow	Forward Exchange Rate	Dollar Value of Yen Cash Flow	Net Cash Flow ($)	Present Value
1	−0.8	60	0.009557	0.5734	−0.2266	−0.2071
2	−0.8	60	0.010047	0.6028	−0.1972	−0.1647
3	−0.8	60	0.010562	0.6337	−0.1663	−0.1269
3	−10.0	1200	0.010562	12.6746	+2.6746	2.0417
Total:						1.5430

million dollars. This is the value of a forward contract corresponding to the exchange of cash flows at the end of year 1. The value of the other forward contracts are calculated similarly. As shown in Table 10-10, the total value of the forward contracts is $1.5430 million. This agrees with the value calculated for the swap in Example 10.4 by decomposing it into bonds.

The value of a currency swap is normally close to zero initially. If the two principals are worth the same at the start of the swap, the value of the swap is also close to zero immediately after the initial exchange of principal. However, as in the case of interest rate swaps, this does not mean that each of the individual forward contracts underlying the swap has a value close to zero. It can be shown that, when interest rates in two currencies are significantly different, the payer of the currency with the high interest rate is in the position where the forward contracts corresponding to the early exchanges of cash flows have negative values, and the forward contract corresponding to final exchange of principals has a positive value. The payer of the currency with the low interest rate is in the opposite position; that is, the forward contracts corresponding to the early exchanges of cash flows have positive values, while that corresponding to the final exchange has a negative value. These results are important when the credit risk in the swap is being evaluated.

OTHER CURRENCY SWAPS

Two other popular currency swaps are:

1. Fixed-for-floating where a floating interest rate in one currency is exchanged for a fixed interest rate in another currency
2. Floating-for-floating where a floating interest rate in one currency is exchanged for a floating interest rate in another currency.

An example of the first type of swap would be an exchange where sterling LIBOR on a principal of £7 million is paid and 3% on a principal of $10 million is received with payments being made semiannually for 10 years. Similarly to a fixed-for-fixed currency swap, this would involve an initial exchange of principal in the opposite direction to the interest payments and a final exchange of principal in the same direction as the interest payments at the end of the swap's life. A fixed-for-floating swap can be regarded as a portfolio consisting of a fixed-for-fixed currency swap and a fixed-for-floating interest rate swap. For instance, the swap in our example can be regarded as (a) a swap where 3% on a principal of $10 million is received and (say) 4% on a principal of £7 million is paid plus (b) an interest rate swap where 4% is received and LIBOR is paid on a notional principal of £7 million.

To value the swap we are considering, we can calculate the value of the dollar payments in dollars by discounting them at the dollar risk-free rate. We can calculate the value of the sterling payments by assuming that sterling LIBOR forward rates will be realized and discounting the cash flows at the sterling risk-free rate. The value of the swap is the difference between the values of the two sets of payments using current exchange rates.

An example of the second type of swap would be the exchange where sterling LIBOR on a principal of £7 million is paid and dollar LIBOR on a principal of $10 million is received. As in the other cases we have considered, this would involve an initial exchange of principal in the opposite direction to the interest payments and a final exchange of principal in the same direction as the interest

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payments at the end of the swap's life. A floating-for-floating swap can be regarded as a portfolio consisting of a fixed-for-fixed currency swap and two interest rate swaps, one in each currency. For instance, the swap in our example can be regarded as (a) a swap where (say) 3% on a principal of $10 million is received and (say) 4% on a principal of £7 million is paid plus (b) an interest rate swap where 4% is received and LIBOR is paid on a notional principal of £7 million plus (c) an interest rate swap where 3% is paid and LIBOR is received on a notional principal of $10 million.

A floating-for-floating swap can be valued by assuming that forward interest rates in each currency will be realized and discounting the cash flows at risk-free rates. The value of the swap is the difference between the values of the two sets of payments using current exchange rates.

CREDIT RISK

Transactions such as swaps that are private arrangements between two companies entail credit risks. Consider a financial institution that has entered into offsetting transactions with two companies (see Figure 10-4, 10-5, or 10-7). If neither party defaults, the financial institution remains fully hedged. A decline in the value of one transaction will always be offset by an increase in the value of the other transaction. However, there is a chance that one party will get into financial difficulties and default. The financial institution then still has to honor the contract it has with the other party.

Suppose that, some time after the initiation of the transactions in Figure 10-4, the transaction with Microsoft has a positive value to the financial institution, whereas the transaction with Intel has a negative value. Suppose further that the financial institution has no other derivatives transactions with these companies and that no collateral is posted. If Microsoft defaults, the financial institution is liable to lose the whole of the positive value it has in this transaction. To maintain a hedged position, it would have to find a third party willing to take Microsoft's position. To induce the third party to take the position, the financial institution would have to pay the third party an amount roughly equal to the value of its contract with Microsoft prior to the default.

A financial institution clearly has credit-risk exposure from a swap when the value of the swap to the financial institution is positive. What happens when this value is negative and the counterparty gets into financial difficulties? In theory, the financial institution could realize a windfall gain, because a default would lead to it getting rid of a liability. In practice, it is likely that the counterparty would choose to sell the transaction to a third party or rearrange its affairs in some way so that its positive value in the transaction is not lost. The most realistic assumption for the financial institution is therefore as follows. If the counterparty goes bankrupt, there will be a loss if the value of the swap to the financial institution is positive, and there will be no effect on the financial institution's position if the value of the swap to the financial institution is negative. This situation is summarized in Figure 10-14.

In swaps, it is sometimes the case that the early exchanges of cash flows have positive values and the later exchanges have negative values. (This would be true in Figure 10-9a and in a currency swap where the currency with the lower interest rate is paid.) These swaps are likely to have negative values for most of their lives and therefore entail less credit risk than swaps where the reverse is true.

Potential losses from defaults on a swap are much less than the potential losses from defaults on a loan with the same principal. This is because the value of the swap is usually only a small fraction of the value of the loan. Potential losses from defaults on a currency swap are greater than on an interest rate swap. The reason is that, because principal amounts in two different currencies are exchanged at the end of the life of a currency swap, a currency swap is liable to have a greater value at the time of a default than an interest rate swap.

It is important to distinguish between the credit risk and market risk to a financial institution in any contract. As

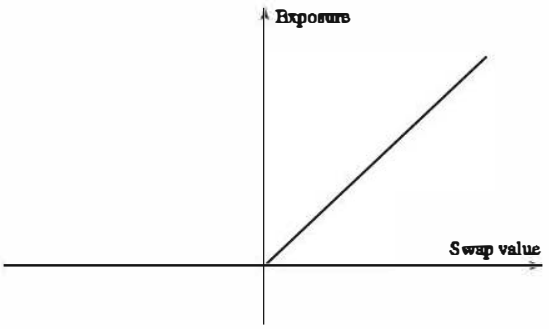

FIGURE 10-14 The credit exposure on a portfolio consisting of a single uncollateralized swap.

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discussed earlier, the credit risk arises from the possibility of a default by the counterparty when the value of the contract to the financial institution is positive. The market risk arises from the possibility that market variables such as interest rates and exchange rates will move in such a way that the value of a contract to the financial institution becomes negative. Market risks can be hedged relatively easily by entering into offsetting contracts; credit risks are less easy to hedge.

One of the more bizarre stories in swap markets is outlined in Box 10-2. It concerns the British Local Authority Hammersmith and Fulham and shows that, in addition to bearing market risk and credit risk, banks trading swaps also sometimes bear legal risk.

BOX 10-2 The Hammersmith and Fulham Story

Between 1987 to 1989 the London Borough of Hammersmith and Fulham in the UK entered into about 600 interest rate swaps and related instruments with a total notional principal of about 6 billion pounds. The transactions appear to have been entered into for speculative rather than hedging purposes. The two employees of Hammersmith and Fulham responsible for the trades had only a sketchy understanding of the risks they were taking and how the products they were trading worked.

By 1989, because of movements in sterling interest rates, Hammersmith and Fulham had lost several hundred million pounds on the swaps. To the banks on the other side of the transactions, the swaps were worth several hundred million pounds. The banks were concerned about credit risk. They had entered into off-setting swaps to hedge their interest rate risks. If Hammersmith and Fulham defaulted, the banks would still have to honor their obligations on the offsetting swaps and would take a huge loss.

What happened was something a little different from a default. Hammersmith and Fulham's auditor asked to have the transactions declared void because Hammersmith and Fulham did not have the authority to enter into the transactions. The British courts agreed. The case was appealed and went all the way to the House of Lords, Britain's highest court. The final decision was that Hammersmith and Fulham did not have the authority to enter into the swaps, but that they ought to have the authority to do so in the future for risk-management purposes. Needless to say, banks were furious that their contracts were overturned in this way by the courts.

Central Clearing

As explained in Chapter 5, in an attempt to reduce credit risk in over-the-counter markets, regulators require standardized over-the-counter derivatives to be cleared through central counterparties (CCPs). The CCP acts as an intermediary between the two sides in a transaction. It requires initial margin and variation margin from both sides in the same way that these are required by futures clearing houses. LCH.Clearnet (formed by a merger of the London Clearing House and Paris-based Clearnet) is the largest CCP for interest rate swaps. It was clearing swaps with over $350 trillion of notional principal in 2013.

Credit Default Swaps

A swap which has grown in importance since the year 2000 is a *credit default swap* (CDS). This is a swap that allows companies to hedge credit risks in the same way that they have hedged market risks for many years. A CDS is like an insurance contract that pays off if a particular company or country defaults. The company or country is known as the *reference entity*. The buyer of credit protection pays an insurance premium, known as the *CDS spread*, to the seller of protection for the life of the contract or until the reference entity defaults. Suppose that the notional principal of the CDS is $100 million and the CDS spread for a 5-year deal is 120 basis points. The insurance premium would be 120 basis points applied to $100 million or $1.2 million per year. If the reference entity does not default during the 5 years, nothing is received in return for the insurance premiums. If reference entity does default and bonds issued by the reference entity are worth 40 cents per dollar of principal immediately after default, the seller of protection has to make a payment to the buyer of protection equal to $60 million. The idea here is that, if the buyer of protection owned a portfolio of bonds issued by the reference entity with a principal of $100 million, the payoff would be sufficient to bring the value of the portfolio back up to $100 million.

OTHER TYPES OF SWAPS

In this chapter, we have covered interest rate swaps where LIBOR is exchanged for a fixed rate of interest and currency swaps where interest in one currency is exchanged for interest in another currency. Many other types of swaps are traded. At this stage, we will provide an overview.

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Variations on the Standard Interest Rate Swap

In fixed-for-floating interest rate swaps, LIBOR is the most common reference floating interest rate. In the examples in this chapter, the tenor (i.e., payment frequency) of LIBOR has been 6 months, but swaps where the tenor of LIBOR is 1 month, 3 months, and 12 months trade regularly. The tenor on the floating side does not have to match the tenor on the fixed side. (Indeed, as pointed out in footnote 3, the standard interest rate swap in the United States is one where there are quarterly LIBOR payments and semiannual fixed payments.) LIBOR is the most common floating rate, but others such as the commercial paper (CP) rate are occasionally used. Sometimes what are known as *basis swaps* are negotiated. For example, the 3-month CP rate plus 10 basis points might be exchanged for 3-month LIBOR with both being applied to the same principal. (This deal would allow a company to hedge its exposure when assets and liabilities are subject to different floating rates.)

The principal in a swap agreement can be varied throughout the term of the swap to meet the needs of a counterparty. In an *amortizing swap*, the principal reduces in a predetermined way. (This might be designed to correspond to the amortization schedule on a loan.) In a *step-up swap*, the principal increases in a predetermined way. (This might be designed to correspond to drawdowns on a loan agreement.) Deferred swaps or *forward swaps*, where the parties do not begin to exchange interest payments until some future date, can also be arranged. Sometimes swaps are negotiated where the principal to which the fixed payments are applied is different from the principal to which the floating payments are applied.

A *constant maturity swap* (CMS swap) is an agreement to exchange a LIBOR rate for a swap rate. An example would be an agreement to exchange 6-month LIBOR applied to a certain principal for the 10-year swap rate applied to the same principal every 6 months for the next 5 years. A *constant maturity Treasury swap* (CMT swap) is a similar agreement to exchange a LIBOR rate for a particular Treasury rate (e.g., the 10-year Treasury rate).

In a *compounding swap*, interest on one or both sides is compounded forward to the end of the life of the swap according to preagreed rules and there is only one payment date at the end of the life of the swap. In a *LIBOR-in arrears* swap, the LIBOR rate observed on a payment date is used to calculate the payment on that date. (As explained in the first section, in a standard deal the LIBOR rate observed on one payment date is used to determine the payment on the next payment date.) In an *accrual swap*, the interest on one side of the swap accrues only when the floating reference rate is in a certain range.

Diff Swaps

Sometimes a rate observed in one currency is applied to a principal amount in another currency. One such deal might be where 3-month LIBOR observed in the United States is exchanged for 3-month LIBOR in Britain, with both rates being applied to a principal of 10 million British pounds. This type of swap is referred to as a *diff swap* or a *quanto*.

Equity Swaps

An *equity swap* is an agreement to exchange the total return (dividends and capital gains) realized on an equity index for either a fixed or a floating rate of interest. For example, the total return on the S&P 500 in successive 6-month periods might be exchanged for LIBOR, with both being applied to the same principal. Equity swaps can be used by portfolio managers to convert returns from a fixed or floating investment to the returns from investing in an equity index, and vice versa.

Options

Sometimes there are options embedded in a swap agreement. For example, in an *extendable swap*, one party has the option to extend the life of the swap beyond the specified period. In a *puttable swap*, one party has the option to terminate the swap early. Options on swaps, or *swaptions*, are also available. These provide one party with the right at a future time to enter into a swap where a predetermined fixed rate is exchanged for floating.

Commodity Swaps, Volatility Swaps, and Other Exotic Instruments

Commodity swaps are in essence a series of forward contracts on a commodity with different maturity dates and the same delivery prices. In a *volatility swap* there are a series of time periods. At the end of each period, one side pays a preagreed volatility, while the other side pays the historical volatility realized during the period. Both

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volatilities are multiplied by the same notional principal in calculating payments.

Swaps are limited only by the imagination of financial engineers and the desire of corporate treasurers and fund managers for exotic structures. For example, there was the famous 5/30 swap entered into between Procter and Gamble and Bankers Trust, where payments depended in a complex way on the 30-day commercial paper rate, a 30-year Treasury bond price, and the yield on a 5-year Treasury bond.

SUMMARY

The two most common types of swaps are interest rate swaps and currency swaps. In an interest rate swap, one party agrees to pay the other party interest at a fixed rate on a notional principal for a number of years. In return, it receives interest at a floating rate on the same notional principal for the same period of time. In a currency swap, one party agrees to pay interest on a principal amount in one currency. In return, it receives interest on a principal amount in another currency.

Principal amounts are not usually exchanged in an interest rate swap. In a currency swap, principal amounts are usually exchanged at both the beginning and the end of the life of the swap. For a party paying interest in the foreign currency, the foreign principal is received, and the domestic principal is paid at the beginning of the swap's life. At the end of the swap's life, the foreign principal is paid and the domestic principal is received.

An interest rate swap can be used to transform a floating-rate loan into a fixed-rate loan, or vice versa. It can also be used to transform a floating-rate investment to a fixed-rate investment, or vice versa. A currency swap can be used to transform a loan in one currency into a loan in another currency. It can also be used to transform an investment denominated in one currency into an investment denominated in another currency.

There are two ways of valuing interest rate and currency swaps. In the first, the swap is decomposed into a long position in one bond and a short position in another bond. In the second it is regarded as a portfolio of forward contracts.

When a financial institution enters into a pair of offsetting swaps with different counterparties, it is exposed to credit risk. If one of the counterparties defaults when the financial institution has positive value in its swap with that counterparty, the financial institution is liable to lose money because it still has to honor its swap agreement with the other counterparty.

Further Reading

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Mechanics of Options Markets

11

Learning Objectives

After completing this reading you should be able to:

- Describe the types, position variations, and typical underlying assets of options.
- Explain the specification of exchange-traded stock option contracts, including that of nonstandard products.
- Describe how trading, commissions, margin requirements, and exercise typically work for exchange-traded options.

Excerpt is Chapter 10 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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We introduced options in Chapter 4. This chapter explains how options markets are organized, what terminology is used, how the contracts are traded, how margin requirements are set, and so on. This chapter is concerned primarily with stock options. It also presents some introductory material on currency options, index options, and futures options.

Options are fundamentally different from forward and futures contracts. An option gives the holder of the option the right to do something, but the holder does not have to exercise this right. By contrast, in a forward or futures contract, the two parties have committed themselves to some action. It costs a trader nothing (except for the margin/collateral requirements) to enter into a forward or futures contract, whereas the purchase of an option requires an up-front payment.

When charts showing the gain or loss from options trading are produced, the usual practice is to ignore the time value of money, so that the profit is the final payoff minus the initial cost. This chapter follows this practice.

TYPES OF OPTIONS

As mentioned in Chapter 4, there are two types of options. A *call option* gives the holder of the option the right to buy an asset by a certain date for a certain price. A *put option* gives the holder the right to sell an asset by a certain date for a certain price. The date specified in the contract is known as the *expiration date* or the *maturity date*. The price specified in the contract is known as the *exercise price* or the *strike price*.

Options can be either American or European, a distinction that has nothing to do with geographical location. *American options* can be exercised at any time up to the expiration date, whereas *European options* can be exercised only on the expiration date itself. Most of the options that are traded on exchanges are American. However, European options are generally easier to analyze than American options, and some of the properties of an American option are frequently deduced from those of its European counterpart.

Call Options

Consider the situation of an investor who buys a European call option with a strike price of $100 to purchase 100 shares of a certain stock. Suppose that the current stock price is $98, the expiration date of the option is in 4 months, and the price of an option to purchase one share is $5. The initial investment is $500. Because the option is European, the investor can exercise only on the expiration date. If the stock price on this date is less than $100, the investor will clearly choose not to exercise. (There is no point in buying for $100 a share that has a market value of less than $100.) In these circumstances, the investor loses the whole of the initial investment of $500. If the stock price is above $100 on the expiration date, the option will be exercised. Suppose, for example, that the stock price is $115. By exercising the option, the investor is able to buy 100 shares for $100 per share. If the shares are sold immediately, the investor makes a gain of $15 per share, or $1,500, ignoring transaction costs. When the initial cost of the option is taken into account, the net profit to the investor is $1,000.

Figure 11-1 shows how the investor's net profit or loss on an option to purchase one share varies with the final stock price in the example. For example, when the final stock price is $120, the profit from an option to purchase one share is $15. It is important to realize that an investor sometimes exercises an option and makes a loss overall. Suppose that, in the example, the stock price is $102 at the expiration of the option. The investor would exercise for a gain of $102 − $100 = $2 and realize a loss overall of $3 when the initial cost of the option is taken into

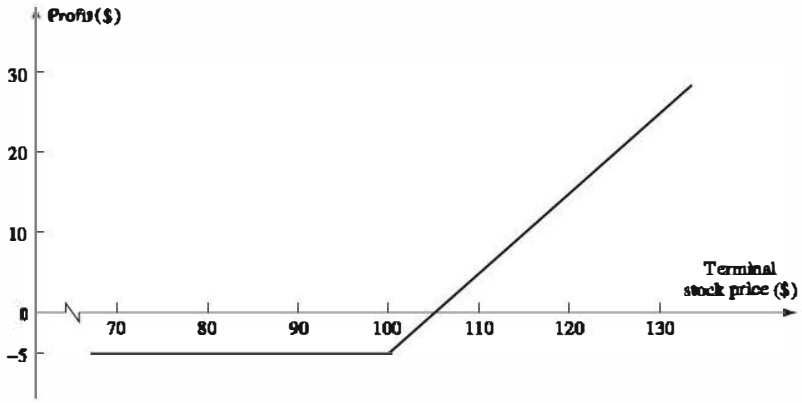

FIGURE 11-1 Profit from buying a European call option on one share of a stock. Option price = $5; strike price = $100.

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account. It is tempting to argue that the investor should not exercise the option in these circumstances. However, not exercising would lead to a loss of $5, which is worse than the $3 loss when the investor exercises. In general, call options should always be exercised at the expiration date if the stock price is above the strike price.

Put Options

Whereas the purchaser of a call option is hoping that the stock price will increase, the purchaser of a put option is hoping that it will decrease. Consider an investor who buys a European put option with a strike price of $70 to sell 100 shares of a certain stock. Suppose that the current stock price is $65, the expiration date of the option is in 3 months, and the price of an option to sell one share is $7. The initial investment is $700. Because the option is European, it will be exercised only if the stock price is below $70 on the expiration date. Suppose that the stock price is $55 on this date. The investor can buy 100 shares for $55 per share and, under the terms of the put option, sell the same shares for $70 to realize a gain of $15 per share, or $1,500. (Again, transaction costs are ignored.) When the $700 initial cost of the option is taken into account, the investor's net profit is $800. There is no guarantee that the investor will make a gain. If the final stock price is above $70, the put option expires worthless, and the investor loses $700. Figure 11-2 shows the way in which the investor's profit or loss on an option to sell one share varies with the terminal stock price in this example.

Early Exercise

As mentioned earlier, exchange-traded stock options are usually American rather than European. This means that the investor in the foregoing examples would not have to wait until the expiration date before exercising the option. We will see later that there are some circumstances when it is optimal to exercise American options before the expiration date.

OPTION POSITIONS

There are two sides to every option contract. On one side is the investor who has taken the long position (i.e., has bought the option). On the other side is the investor who has taken a short position (i.e., has sold or *written* the option). The writer of an option receives cash up front, but has potential liabilities later. The writer's profit or loss is the reverse of that for the purchaser of the option. Figures 11-3 and 11-4 show the variation of the profit or loss with the final stock price for writers of the options considered in Figures 11-1 and 11-2.

There are four types of option positions:

1. A long position in a call option
2. A long position in a put option
3. A short position in a call option
4. A short position in a put option.

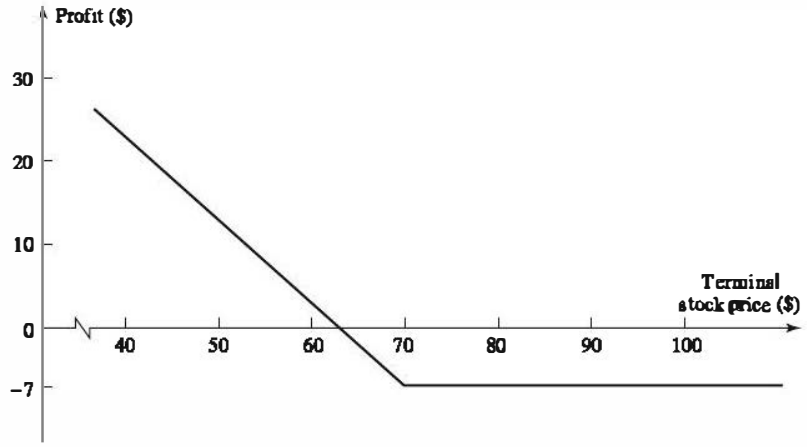

FIGURE 11-2 Profit from buying a European put option on one share of a stock. Option price = $7; strike price = $70.

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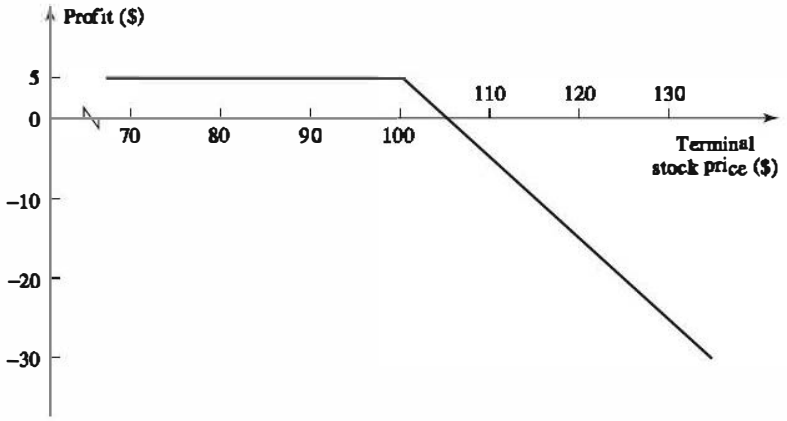

FIGURE 11-3 Profit from writing a European call option on one share of a stock. Option price = $5; strike price = $100.

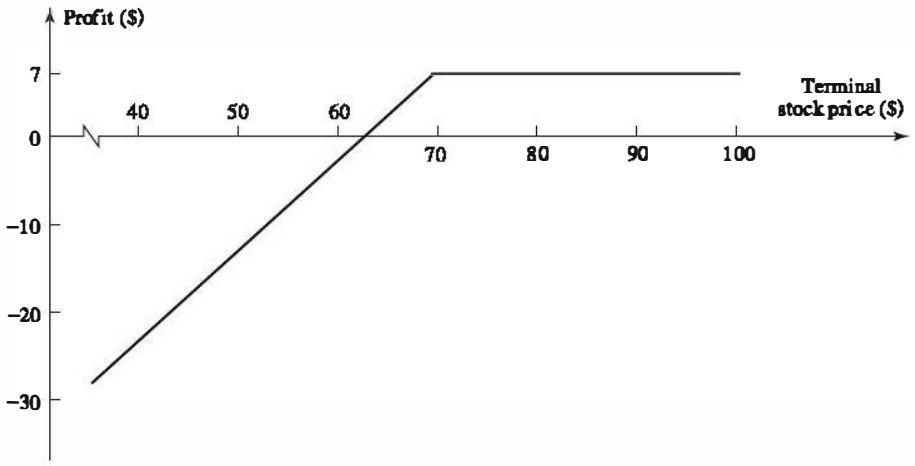

FIGURE 11-4 Profit from writing a European put option on one share of a stock. Option price = $7; strike price = $70.

It is often useful to characterize a European option in terms of its payoff to the purchaser of the option. The initial cost of the option is then not included in the calculation. If K is the strike price and S_T is the final price of the underlying asset, the payoff from a long position in a European call option is

$$\max(S_T - K, 0)$$

This reflects the fact that the option will be exercised if $S_T > K$ and will not be exercised if $S_T \leq K$. The payoff to the holder of a short position in the European call option is

$$-\max(S_T - K, 0) = \min(K - S_T, 0)$$

The payoff to the holder of a long position in a European put option is

$$\max(K - S_T, 0)$$

and the payoff from a short position in a European put option is

$$-\max(K - S_T, 0) = \min(S_T - K, 0)$$

Figure 11-5 illustrates these payoffs.

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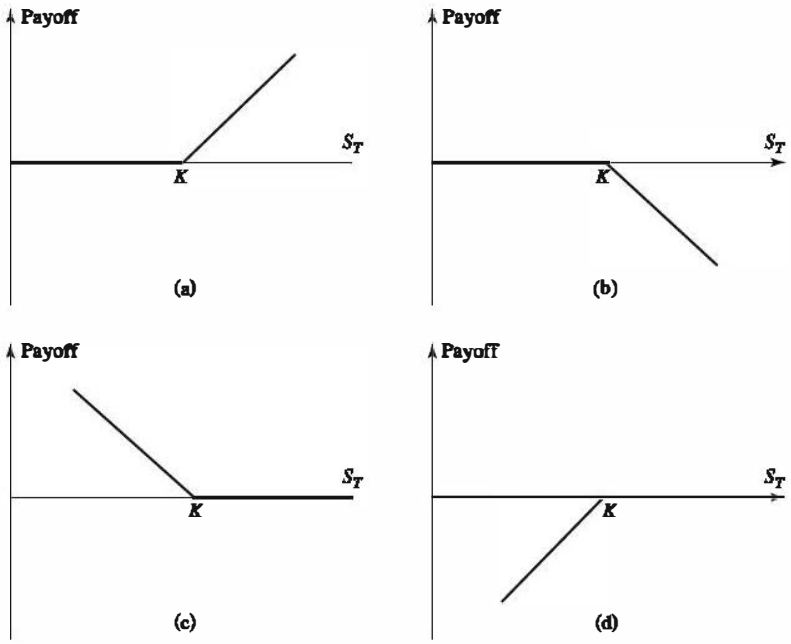

FIGURE 11-5 Payoffs from positions in European options: (a) long call; (b) short call; (c) long put; (d) short put. Strike price = K; price of asset at maturity = S_T.

UNDERLYING ASSETS

This section provides a first look at how options on stocks, currencies, stock indices, and futures are traded on exchanges.

Stock Options

Most trading in stock options is on exchanges. In the United States, the exchanges include the Chicago Board Options Exchange (www.cboe.com), NYSE Euronext (www.euronext.com), which acquired the American Stock Exchange in 2008, the International Securities Exchange (www.iseoptions.com), and the Boston Options Exchange (www.bostonoptions.com). Options trade on several thousand different stocks. One contract gives the holder the right to buy or sell 100 shares at the specified strike price. This contract size is convenient because the shares themselves are normally traded in lots of 100.

Foreign Currency Options

Most currency options trading is now in the over-the-counter market, but there is some exchange trading. Exchanges trading foreign currency options in the United States include NASDAQ OMX (www.nasdaqtrader.com), which acquired the Philadelphia Stock Exchange in 2008. This exchange offers European-style contracts on a variety of different currencies. One contract is to buy or sell 10,000 units of a foreign currency (1,000,000 units in the case of the Japanese yen) for US dollars.

Index Options

Many different index options currently trade throughout the world in both the over-the-counter market and the exchange-traded market. The most popular exchange-traded contracts in the United States are those on the S&P 500 Index (SPX), the S&P 100 Index (OEX), the Nasdaq-100 Index (NDX), and the Dow Jones Industrial Index (DJX). All of these trade on the Chicago Board Options Exchange. Most of the contracts are European. An exception is the OEX contract on the S&P 100, which is American. One contract is usually to buy or sell 100 times the index at the specified strike price. Settlement is always in cash, rather than by delivering the portfolio underlying the index. Consider, for example, one call contract on an index with a strike price of 980. If it is exercised when the

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value of the index is 992, the writer of the contract pays the holder (992 − 980) × 100 = $1,200.

Futures Options

When an exchange trades a particular futures contract, it often also trades American options on that contract. The life of a futures option normally ends a short period of time before the expiration of trading in the underlying futures contract. When a call option is exercised, the holder's gain equals the excess of the futures price over the strike price. When a put option is exercised, the holder's gain equals the excess of the strike price over the futures price.

SPECIFICATION OF STOCK OPTIONS

In the rest of this chapter, we will focus on stock options. As already mentioned, a standard exchange-traded stock option in the United States is an American-style option contract to buy or sell 100 shares of the stock. Details of the contract (the expiration date, the strike price, what happens when dividends are declared, how large a position investors can hold, and so on) are specified by the exchange.

Expiration Dates

One of the items used to describe a stock option is the month in which the expiration date occurs. Thus, a January call trading on IBM is a call option on IBM with an expiration date in January. The precise expiration date is the Saturday immediately following the third Friday of the expiration month. The last day on which options trade is the third Friday of the expiration month. An investor with a long position in an option normally has until 4:30 p.m. Central Time on that Friday to instruct a broker to exercise the option. The broker then has until 10:59 p.m. the next day to complete the paperwork notifying the exchange that exercise is to take place.

Stock options in the United States are on a January, February, or March cycle. The January cycle consists of the months of January, April, July, and October. The February cycle consists of the months of February, May, August, and November. The March cycle consists of the months of March, June, September, and December. If the expiration date for the current month has not yet been reached, options trade with expiration dates in the current month, the following month, and the next two months in the cycle. If the expiration date of the current month has passed, options trade with expiration dates in the next month, the next-but-one month, and the next two months of the expiration cycle. For example, IBM is on a January cycle. At the beginning of January, options are traded with expiration dates in January, February, April, and July; at the end of January, they are traded with expiration dates in February, March, April, and July; at the beginning of May, they are traded with expiration dates in May, June, July, and October; and so on. When one option reaches expiration, trading in another is started. Longer-term options, known as LEAPS (long-term equity anticipation securities), also trade on many stocks in the United States. These have expiration dates up to 39 months into the future. The expiration dates for LEAPS on stocks are always in January.

Strike Prices

The exchange normally chooses the strike prices at which options can be written so that they are spaced $2.50, $5, or $10 apart. Typically the spacing is $2.50 when the stock price is between $5 and $25, $5 when the stock price is between $25 and $200, and $10 for stock prices above $200. As will be explained shortly, stock splits and stock dividends can lead to nonstandard strike prices.

When a new expiration date is introduced, the two or three strike prices closest to the current stock price are usually selected by the exchange. If the stock price moves outside the range defined by the highest and lowest strike price, trading is usually introduced in an option with a new strike price. To illustrate these rules, suppose that the stock price is $84 when trading begins in the October options. Call and put options would probably first be offered with strike prices of $80, $85, and $90. If the stock price rose above $90, it is likely that a strike price of $95 would be offered; if it fell below $80, it is likely that a strike price of $75 would be offered; and so on.

Terminology

For any given asset at any given time, many different option contracts may be trading. Suppose there are four expiration dates and five strike prices for options on a particular stock. If call and put options trade with every expiration date and every strike price, there are a total of 40 different contracts. All options of the same type (calls or puts) on a stock are referred to as an *option class*. For example, IBM calls are one class, whereas IBM puts are

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another class. An *option series* consists of all the options of a given class with the same expiration date and strike price. In other words, it refers to a particular contract that is traded. For example, IBM 200 October 2014 calls would constitute an option series.

Options are referred to as *in the money, at the money,* or *out of the money.* If S is the stock price and K is the strike price, a call option is in the money when $S > K$, at the money when $S = K$, and out of the money when $S < K$. A put option is in the money when $S < K$, at the money when $S = K$, and out of the money when $S > K$. Clearly, an option will be exercised only when it is in the money. In the absence of transaction costs, an in-the-money option will always be exercised on the expiration date if it has not been exercised previously.

The *intrinsic value* of an option is defined as the value it would have if there were no time to maturity, so that the exercise decision had to be made immediately. For a call option, the intrinsic value is therefore $\max(S - K, 0)$. For a put option, it is $\max(K - S, 0)$. An in-the-money American option must be worth at least as much as its intrinsic value because the holder has the right to exercise it immediately. Often it is optimal for the holder of an in-the-money American option to wait rather than exercise immediately. The option is then said to have *time value*. The total value of an option can be thought of as the sum of its intrinsic value and its time value.

FLEX Options

The Chicago Board Options Exchange offers FLEX (short for flexible) options on equities and equity indices. These are options where the traders agree to nonstandard terms. These nonstandard terms can involve a strike price or an expiration date that is different from what is usually offered by the exchange. They can also involve the option being European rather than American. FLEX options are an attempt by option exchanges to regain business from the over-the-counter markets. The exchange specifies a minimum size (e.g., 100 contracts) for FLEX option trades.

Other Nonstandard Products

In addition to flex options, the CBOE trades a number of other nonstandard products. Examples are:

1. Options on exchange-traded funds.[1]
2. *Weeklys.* These are options that are created on a Thursday and expire on Friday of the following week.
3. *Binary options.* These are options that provide a fixed payoff of $100 if the strike price is reached. For example, a binary call with a strike price of $50 provides a payoff of $100 if the price of the underlying stock exceeds $50 on the expiry date; a binary put with a strike price of $50 provides a payoff of $100 if the price of the stock is below $50 on the expiry date. Binary options are discussed further in Chapter 14.
4. *Credit event binary options* (CEBOs). These are options that provide a fixed payoff if a particular company (known as the reference entity) suffers a "credit event" by the maturity date. Credit events are defined as bankruptcy, failure to pay interest or principal on debt, and a restructuring of debt. Maturity dates are in December of a particular year and payoffs, if any, are made on the maturity date. ACEBO is a type of credit default swap (see Chapter 10 for an introduction to credit default swaps).
5. *DOOM options.* These are deep-out-of-the-money put options. Because they have a low strike price, they cost very little. They provide a payoff only if the price of the underlying asset plunges. DOOM options provide the same sort of protection as credit default swaps.

Dividends and Stock Splits

The early over-the-counter options were dividend protected. If a company declared a cash dividend, the strike price for options on the company's stock was reduced on the ex-dividend day by the amount of the dividend. Exchange-traded options are not usually adjusted for cash dividends. In other words, when a cash dividend occurs, there are no adjustments to the terms of the option contract. An exception is sometimes made for large cash dividends (see Box 11-1).

[1] Exchange-traded funds (ETFs) have become a popular alternative to mutual funds for investors. They are traded like stocks and are designed so that their prices reflect the value of the assets of the fund closely.

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BOX 11-1 Gucci Group's Large Dividend

When there is a large cash dividend (typically one that is more than 10% of the stock price), a committee of the Options Clearing Corporation (OCC) at the Chicago Board Options Exchange can decide to adjust the terms of options traded on the exchange.

On May 28, 2003, Gucci Group NV (GUC) declared a cash dividend of 13.50 euros (approximately $15.88) per common share and this was approved at the annual shareholders' meeting on July 16, 2003. The dividend was about 16% of the share price at the time it was declared. In this case, the OCC committee decided to adjust the terms of options. The result was that the holder of a call contract paid 100 times the strike price on exercise and received $1,588 of cash in addition to 100 shares; the holder of a put contract received 100 times the strike price on exercise and delivered $1,588 of cash in addition to 100 shares. These adjustments had the effect of reducing the strike price by $15.88.

Adjustments for large dividends are not always made. For example, Deutsche Terminbörse chose not to adjust the terms of options traded on that exchange when Daimler-Benz surprised the market on March 10, 1998, with a dividend equal to about 12% of its stock price.

Exchange-traded options are adjusted for stock splits. A stock split occurs when the existing shares are "split" into more shares. For example, in a 3-for-1 stock split, three new shares are issued to replace each existing share. Because a stock split does not change the assets or the earning ability of a company, we should not expect it to have any effect on the wealth of the company's shareholders. All else being equal, the 3-for-1 stock split should cause the stock price to go down to one-third of its previous value. In general, an *n*-for-*m* stock split should cause the stock price to go down to *m/n* of its previous value. The terms of option contracts are adjusted to reflect expected changes in a stock price arising from a stock split. After an *n*-for-*m* stock split, the strike price is reduced to *m/n* of its previous value, and the number of shares covered by one contract is increased to *n/m* of its previous value. If the stock price declines in the way expected, the positions of both the writer and the purchaser of a contract remain unchanged.

Example 11.1

Consider a call option to buy 100 shares of a company for $30 per share. Suppose the company makes a 2-for-1 stock split. The terms of the option contract are then changed so that it gives the holder the right to purchase 200 shares for $15 per share.

Stock options are adjusted for stock dividends. A stock dividend involves a company issuing more shares to its existing shareholders. For example, a 20% stock dividend means that investors receive one new share for each five already owned. A stock dividend, like a stock split, has no effect on either the assets or the earning power of a company. The stock price can be expected to go down as a result of a stock dividend. The 20% stock dividend referred to is essentially the same as a 6-for-5 stock split. All else being equal, it should cause the stock price to decline to 5/6 of its previous value. The terms of an option are adjusted to reflect the expected price decline arising from a stock dividend in the same way as they are for that arising from a stock split.

Example 11.2

Consider a put option to sell 100 shares of a company for $15 per share. Suppose the company declares a 25% stock dividend. This is equivalent to a 5-for-4 stock split. The terms of the option contract are changed so that it gives the holder the right to sell 125 shares for $12.

Adjustments are also made for rights issues. The basic procedure is to calculate the theoretical price of the rights and then to reduce the strike price by this amount.

Position Limits and Exercise Limits

The Chicago Board Options Exchange often specifies a *position limit* for option contracts. This defines the maximum number of option contracts that an investor can hold on one side of the market. For this purpose, long calls and short puts are considered to be on the same side of the market. Also considered to be on the same side are short calls and long puts. The *exercise limit* usually equals the position limit. It defines the maximum number of contracts that can be exercised by any individual (or group of individuals acting together) in any period of five consecutive business days. Options on the largest and most frequently traded stocks have positions limits of 250,000 contracts. Smaller capitalization stocks have position limits of 200,000, 75,000, 50,000, or 25,000 contracts.

Position limits and exercise limits are designed to prevent the market from being unduly influenced by the activities of an individual investor or group of investors.

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However, whether the limits are really necessary is a controversial issue.

TRADING

Traditionally, exchanges have had to provide a large open area for individuals to meet and trade options. This has changed. Most derivatives exchanges are fully electronic, so traders do not have to physically meet. The International Securities Exchange (www.iseoptions.com) launched the first all-electronic options market for equities in the United States in May 2000. Over 95% of the orders at the Chicago Board Options Exchange are handled electronically. The remainder are mostly large or complex institutional orders that require the skills of traders.

Market Makers

Most options exchanges use market makers to facilitate trading. A market maker for a certain option is an individual who, when asked to do so, will quote both a bid and an offer price on the option. The bid is the price at which the market maker is prepared to buy, and the offer or asked is the price at which the market maker is prepared to sell. At the time the bid and offer prices are quoted, the market maker does not know whether the trader who asked for the quotes wants to buy or sell the option. The offer is always higher than the bid, and the amount by which the offer exceeds the bid is referred to as the *bid–offer* spread. The exchange sets upper limits for the bid–offer spread. For example, it might specify that the spread be no more than $0.25 for options priced at less than $0.50, $0.50 for options priced between $0.50 and $10, $0.75 for options priced between $10 and $20, and $1 for options priced over $20.

The existence of the market maker ensures that buy and sell orders can always be executed at some price without any delays. Market makers therefore add liquidity to the market. The market makers themselves make their profits from the bid–offer spread.

Offsetting Orders

An investor who has purchased options can close out the position by issuing an offsetting order to sell the same number of options. Similarly, an investor who has written options can close out the position by issuing an offsetting order to buy the same number of options. (In this respect options markets are similar to futures markets.) If, when an option contract is traded, neither investor is closing an existing position, the open interest increases by one contract. If one investor is closing an existing position and the other is not, the open interest stays the same. If both investors are closing existing positions, the open interest goes down by one contract.

COMMISSIONS

The types of orders that can be placed with a broker for options trading are similar to those for futures trading (see Chapter 5). A market order is executed immediately, a limit order specifies the least favorable price at which the order can be executed, and so on.

For a retail investor, commissions vary significantly from broker to broker. Discount brokers generally charge lower commissions than full-service brokers. The actual amount charged is often calculated as a fixed cost plus a proportion of the dollar amount of the trade. Table 11-1 shows the sort of schedule that might be offered by a discount broker. Using this schedule, the purchase of eight contracts when the option price is $3 would cost $20 + (0.02 × $2,400) = $68 in commissions.

If an option position is closed out by entering into an offsetting trade, the commission must be paid again. If the option is exercised, the commission is the same as it would be if the investor placed an order to buy or sell the underlying stock.

Consider an investor who buys one call contract with a strike price of $50 when the stock price is $49. We suppose the option price is $4.50, so that the cost of the contract is $450. Under the schedule in Table 11-1, the

TABLE 11-1 Sample Commission Schedule for a Discount Broker

Dollar Amount of Trade	Commission*
< $2,500	$20 + 2% of dollar amount
$2,500 to $10,000	$45 + 1% of dollar amount
> $10,000	$120 + 0.25% of dollar amount

*Maximum commission is $30 per contract for the first five contracts plus $20 per contract for each additional contract. Minimum commission is $30 per contract for the first contract plus $2 per contract for each additional contract.

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purchase or sale of one contract always costs $30 (both the maximum and minimum commission is $30 for the first contract). Suppose that the stock price rises and the option is exercised when the stock reaches $60. Assuming that the investor pays 0.75% commission to exercise the option and a further 0.75% commission to sell the stock, there is an additional cost of

$$2 \times 0.0075 \times \$60 \times 100 = \$90$$

The total commission paid is therefore $120, and the net profit to the investor is

$$\$1{,}000 - \$450 - \$120 = \$430$$

Note that selling the option for $10 instead of exercising it would save the investor $60 in commissions. (The commission payable when an option is sold is only $30 in our example.) As this example indicates, the commission system can push retail investors in the direction of selling options rather than exercising them.

A hidden cost in option trading (and in stock trading) is the market maker's bid–offer spread. Suppose that, in the example just considered, the bid price was $4.00 and the offer price was $4.50 at the time the option was purchased. We can reasonably assume that a "fair" price for the option is halfway between the bid and the offer price, or $4.25. The cost to the buyer and to the seller of the market maker system is the difference between the fair price and the price paid. This is $0.25 per option, or $25 per contract.

MARGIN REQUIREMENTS

When shares are purchased in the United States, an investor can borrow up to 50% of the price from the broker. This is known as *buying on margin*. If the share price declines so that the loan is substantially more than 50% of the stock's current value, there is a "margin call", where the broker requests that cash be deposited by the investor. If the margin call is not met, the broker sells the stock.

When call and put options with maturities less than 9 months are purchased, the option price must be paid in full. Investors are not allowed to buy these options on margin because options already contain substantial leverage and buying on margin would raise this leverage to an unacceptable level. For options with maturities greater than 9 months investors can buy on margin, borrowing up to 25% of the option value.

A trader who writes options is required to maintain funds in a margin account. Both the trader's broker and the exchange want to be satisfied that the trader will not default if the option is exercised. The amount of margin required depends on the trader's position.

Writing Naked Options

A *naked option* is an option that is not combined with an offsetting position in the underlying stock. The initial and maintenance margin required by the CBOE for a written naked call option is the greater of the following two calculations:

1. A total of 100% of the proceeds of the sale plus 20% of the underlying share price less the amount, if any, by which the option is out of the money
2. A total of 100% of the option proceeds plus 10% of the underlying share price.

For a written naked put option, it is the greater of

1. A total of 100% of the proceeds of the sale plus 20% of the underlying share price less the amount, if any, by which the option is out of the money
2. A total of 100% of the option proceeds plus 10% of the exercise price.

The 20% in the preceding calculations is replaced by 15% for options on a broadly based stock index because a stock index is usually less volatile than the price of an individual stock.

Example 11.3

An investor writes four naked call option contracts on a stock. The option price is $5, the strike price is $40, and the stock price is $38. Because the option is $2 out of the money, the first calculation gives

$$400 \times (5 + 0.2 \times 38 - 2) = \$4{,}240$$

The second calculation gives

$$400 \times (5 + 0.1 \times 38) = \$3{,}520$$

The initial margin requirement is therefore $4,240. Note that, if the option had been a put, it would be $2 in the money and the margin requirement would be

$$400 \times (5 + 0.2 \times 38) = \$5{,}040$$

In both cases, the proceeds of the sale can be used to form part of the margin account.

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A calculation similar to the initial margin calculation (but with the current market price of the contract replacing the proceeds of sale) is repeated every day. Funds can be withdrawn from the margin account when the calculation indicates that the margin required is less than the current balance in the margin account. When the calculation indicates that a greater margin is required, a margin call will be made.

Other Rules

In Chapter 13, we will examine option trading strategies such as covered calls, protective puts, spreads, combinations, straddles, and strangles. The CBOE has special rules for determining the margin requirements when these trading strategies are used. These are described in the *CBOE Margin Manual*, which is available on the CBOE website (www.cboe.com).

As an example of the rules, consider an investor who writes a covered call. This is a written call option when the shares that might have to be delivered are already owned. Covered calls are far less risky than naked calls, because the worst that can happen is that the investor is required to sell shares already owned at below their market value. No margin is required on the written option. However, the investor can borrow an amount equal to 0.5 min(S, K), rather than the usual 0.5S, on the stock position.

THE OPTIONS CLEARING CORPORATION

The Options Clearing Corporation (OCC) performs much the same function for options markets as the clearing house does for futures markets (see Chapter 5). It guarantees that options writers will fulfill their obligations under the terms of options contracts and keeps a record of all long and short positions. The OCC has a number of members, and all option trades must be cleared through a member. If a broker is not itself a member of an exchange's OCC, it must arrange to clear its trades with a member. Members are required to have a certain minimum amount of capital and to contribute to a special fund that can be used if any member defaults on an option obligation.

The funds used to purchase an option must be deposited with the OCC by the morning of the business day following the trade. The writer of the option maintains a margin account with a broker, as described earlier.[2] The broker maintains a margin account with the OCC member that clears its trades. The OCC member in turn maintains a margin account with the OCC.

Exercising an Option

When an investor instructs a broker to exercise an option, the broker notifies the OCC member that clears its trades. This member then places an exercise order with the OCC. The OCC randomly selects a member with an outstanding short position in the same option. The member, using a procedure established in advance, selects a particular investor who has written the option. If the option is a call, this investor is required to sell stock at the strike price. If it is a put, the investor is required to buy stock at the strike price. The investor is said to be *assigned*. The buy/sell transaction takes place on the third business day following the exercise order. When an option is exercised, the open interest goes down by one.

At the expiration of the option, all in-the-money options should be exercised unless the transaction costs are so high as to wipe out the payoff from the option. Some brokers will automatically exercise options for a client at expiration when it is in their client's interest to do so. Many exchanges also have rules for exercising options that are in the money at expiration.

REGULATION

Options markets are regulated in a number of different ways. Both the exchange and Options Clearing Corporations have rules governing the behavior of traders. In addition, there are both federal and state regulatory authorities. In general, options markets have demonstrated a willingness to regulate themselves. There have been no major scandals or defaults by OCC members. Investors can have a high level of confidence in the way the market is run.

The Securities and Exchange Commission is responsible for regulating options markets in stocks, stock indices, currencies, and bonds at the federal level. The Commodity Futures Trading Commission is responsible for regulating

[2] The margin requirements described in the previous section are the minimum requirements specified by the OCC. A broker may require a higher margin from its clients. However, it cannot require a lower margin. Some brokers do not allow their retail clients to write uncovered options at all.

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markets for options on futures. The major options markets are in the states of Illinois and New York. These states actively enforce their own laws on unacceptable trading practices.

TAXATION

Determining the tax implications of option trading strategies can be tricky, and an investor who is in doubt about this should consult a tax specialist. In the United States, the general rule is that (unless the taxpayer is a professional trader) gains and losses from the trading of stock options are taxed as capital gains or losses. The way that capital gains and losses are taxed in the United States was discussed in Chapter 5. For both the holder and the writer of a stock option, a gain or loss is recognized when (a) the option expires unexercised or (b) the option position is closed out. If the option is exercised, the gain or loss from the option is rolled into the position taken in the stock and recognized when the stock position is closed out. For example, when a call option is exercised, the party with a long position is deemed to have purchased the stock at the strike price plus the call price. This is then used as a basis for calculating this party's gain or loss when the stock is eventually sold. Similarly, the party with the short call position is deemed to have sold the stock at the strike price plus the call price. When a put option is exercised, the seller of the option is deemed to have bought the stock for the strike price less the original put price and the purchaser of the option is deemed to have sold the stock for the strike price less the original put price.

Wash Sale Rule

One tax consideration in option trading in the United States is the wash sale rule. To understand this rule, imagine an investor who buys a stock when the price is $60 and plans to keep it for the long term. If the stock price drops to $40, the investor might be tempted to sell the stock and then immediately repurchase it, so that the $20 loss is realized for tax purposes. To prevent this practice, the tax authorities have ruled that when the repurchase is within 30 days of the sale (i.e., between 30 days before the sale and 30 days after the sale), any loss on the sale is not deductible. The disallowance also applies where, within the 61-day period, the taxpayer enters into an option or similar contract to acquire the stock. Thus, selling a stock at a loss and buying a call option within a 30-day period will lead to the loss being disallowed.

Constructive Sales

Prior to 1997, if a United States taxpayer shorted a security while holding a long position in a substantially identical security, no gain or loss was recognized until the short position was closed out. This means that short positions could be used to defer recognition of a gain for tax purposes. The situation was changed by the Tax Relief Act of 1997. An appreciated property is now treated as "constructively sold" when the owner does one of the following:

1. Enters into a short sale of the same or substantially identical property
2. Enters into a futures or forward contract to deliver the same or substantially identical property
3. Enters into one or more positions that eliminate substantially all of the loss and opportunity for gain.

It should be noted that transactions reducing only the risk of loss or only the opportunity for gain should not result in constructive sales. Therefore an investor holding a long position in a stock can buy in-the-money put options on the stock without triggering a constructive sale.

Tax practitioners sometimes use options to minimize tax costs or maximize tax benefits (see Box 11-2). Tax authorities in many jurisdictions have proposed legislation designed to combat the use of derivatives for tax purposes. Before entering into any tax-motivated transaction, a corporate treasurer or private individual should explore in detail how the structure could be unwound in the event of legislative change and how costly this process could be.

WARRANTS, EMPLOYEE STOCK OPTIONS, AND CONVERTIBLES

Warrants are options issued by a financial institution or nonfinancial corporation. For example, a financial institution might issue put warrants on one million ounces of gold and then proceed to create a market for the warrants. To exercise the warrant, the holder would contact the financial institution. A common use of warrants by a nonfinancial corporation is at the time of a bond issue. The corporation issues call warrants on its own stock and

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BOX 11-2 Tax Planning Using Options

As a simple example of a possible tax planning strategy using options, suppose that Country A has a tax regime where the tax is low on interest and dividends and high on capital gains, while Country B has a tax regime where tax is high on interest and dividends and low on capital gains. It is advantageous for a company to receive the income from a security in Country A and the capital gain, if there is one, in Country B. The company would like to keep capital losses in Country A, where they can be used to offset capital gains on other items. All of this can be accomplished by arranging for a subsidiary company in Country A to have legal ownership of the security and for a subsidiary company in Country B to buy a call option on the security from the company in Country A, with the strike price of the option equal to the current value of the security. During the life of the option, income from the security is earned in Country A. If the security price rises sharply, the option will be exercised and the capital gain will be realized in Country B. If it falls sharply, the option will not be exercised and the capital loss will be realized in Country A.

then attaches them to the bond issue to make it more attractive to investors.

Employee stock options are call options issued to employees by their company to motivate them to act in the best interests of the company's shareholders. They are usually at the money at the time of issue. They are now a cost on the income statement of the company in most countries.

Convertible bonds, often referred to as *convertibles*, are bonds issued by a company that can be converted into equity at certain times using a predetermined exchange ratio. They are therefore bonds with an embedded call option on the company's stock.

One feature of warrants, employee stock options, and convertibles is that a predetermined number of options are issued. By contrast, the number of options on a particular stock that trade on the CBOE or another exchange is not predetermined. As people take positions in a particular option series, the number of options outstanding increases; as people close out positions, it declines. Warrants issued by a company on its own stock, employee stock options, and convertibles are different from exchange-traded options in another important way. When these instruments are exercised, the company issues more shares of its own stock and sells them to the option holder for the strike price. The exercise of the instruments therefore leads to an increase in the number of shares of the company's stock that are outstanding. By contrast, when an exchange-traded call option is exercised, the party with the short position buys in the market shares that have already been issued and sells them to the party with the long position for the strike price. The company whose stock underlies the option is not involved in any way.

OVER-THE-COUNTER OPTIONS MARKETS

Most of this chapter has focused on exchange-traded options markets. The over-the-counter market for options has become increasingly important since the early 1980s and is now larger than the exchange-traded market. As explained in Chapter 4, the main participants in over-the-counter markets are financial institutions, corporate treasurers, and fund managers. There is a wide range of assets underlying the options. Over-the-counter options on foreign exchange and interest rates are particularly popular. The chief potential disadvantage of the over-the-counter market is that the option writer may default. This means that the purchaser is subject to some credit risk. In an attempt to overcome this disadvantage, market participants (and regulators) often require counterparties to post collateral. This was discussed in Chapter 5.

The instruments traded in the over-the-counter market are often structured by financial institutions to meet the precise needs of their clients. Sometimes this involves choosing exercise dates, strike prices, and contract sizes that are different from those offered by an exchange. In other cases the structure of the option is different from standard calls and puts. The option is then referred to as an *exotic option*. Chapter 14 describes a number of different types of exotic options.

SUMMARY

There are two types of options: calls and puts. A call option gives the holder the right to buy the underlying asset for a certain price by a certain date. A put option gives the holder the right to sell the underlying asset by a certain date for a certain price. There are four possible positions in options markets: a long position in a call, a short position in a call, a long position in a put, and a

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short position in a put. Taking a short position in an option is known as writing it. Options are currently traded on stocks, stock indices, foreign currencies, futures contracts, and other assets.

An exchange must specify the terms of the option contracts it trades. In particular, it must specify the size of the contract, the precise expiration time, and the strike price. In the United States one stock option contract gives the holder the right to buy or sell 100 shares. The expiration of a stock option contract is 10:59 p.m. Central Time on the Saturday immediately following the third Friday of the expiration month. Options with several different expiration months trade at any given time. Strike prices are at $2½, $5, or $10 intervals, depending on the stock price. The strike price is generally fairly close to the stock price when trading in an option begins.

The terms of a stock option are not normally adjusted for cash dividends. However, they are adjusted for stock dividends, stock splits, and rights issues. The aim of the adjustment is to keep the positions of both the writer and the buyer of a contract unchanged.

Most option exchanges use market makers. A market maker is an individual who is prepared to quote both a bid price (at which he or she is prepared to buy) and an offer price (at which he or she is prepared to sell). Market makers improve the liquidity of the market and ensure that there is never any delay in executing market orders. They themselves make a profit from the difference between their bid and offer prices (known as their bid–offer spread). The exchange has rules specifying upper limits for the bid–offer spread.

Writers of options have potential liabilities and are required to maintain a margin account with their brokers. If it is not a member of the Options Clearing Corporation, the broker will maintain a margin account with a firm that is a member. This firm will in turn maintain a margin account with the Options Clearing Corporation. The Options Clearing Corporation is responsible for keeping a record of all outstanding contracts, handling exercise orders, and so on.

Not all options are traded on exchanges. Many options are traded in the over-the-counter (OTC) market. An advantage of over-the-counter options is that they can be tailored by a financial institution to meet the particular needs of a corporate treasurer or fund manager.

Further Reading

Chicago Board Options Exchange. *Characteristics and Risks of Standardized Options.* Available online at www.optionsclearing.com/about/publications/character-risks.jsp. First published 1994; last updated 2012.

Chicago Board Options Exchange. *Margin Manual*. Available online at www.cboe.com/LearnCenter/workbench/pdfs/MarginManual2000.pdf. 2000.

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Properties of Stock Options

12

Learning Objectives

After completing this reading you should be able to:

- Identify the six factors that affect an option's price, and describe how these six factors affect the price for both European and American options.
- Identify and compute upper and lower bounds for option prices on non-dividend and dividend paying stocks.
- Explain put-call parity and apply it to the valuation of European and American stock options.
- Explain the early exercise features of American call and put options.

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Excerpt is Chapter 11 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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In this chapter, we look at the factors affecting stock option prices. We use a number of different arbitrage arguments to explore the relationships between European option prices, American option prices, and the underlying stock price. The most important of these relationships is put–call parity, which is a relationship between the price of a European call option, the price of a European put option, and the underlying stock price.

The chapter examines whether American options should be exercised early. It shows that it is never optimal to exercise an American call option on a non-dividend-paying stock prior to the option's expiration, but that under some circumstances the early exercise of an American put option on such a stock is optimal. When there are dividends, it can be optimal to exercise either calls or puts early.

FACTORS AFFECTING OPTION PRICES

There are six factors affecting the price of a stock option:

1. The current stock price, S_0
2. The strike price, K
3. The time to expiration, T
4. The volatility of the stock price, σ
5. The risk-free interest rate, r
6. The dividends that are expected to be paid.

In this section, we consider what happens to option prices when there is a change to one of these factors, with all the other factors remaining fixed. The results are summarized in Table 12-1.

Figures 12-1 and 12-2 show how European call and put prices depend on the first five factors in the situation where $S_0 = 50$, $K = 50$, $r = 5\%$ per annum, $\sigma = 30\%$ per annum, $T = 1$ year, and there are no dividends. In this case the call price is 7.116 and the put price is 4.677.

Stock Price and Strike Price

If a call option is exercised at some future time, the payoff will be the amount by which the stock price exceeds the strike price. Call options therefore become more valuable as the stock price increases and less valuable as the strike price increases. For a put option, the payoff on exercise is the amount by which the strike price exceeds the stock price. Put options therefore behave in the opposite way from call options: they become less valuable as the stock price increases and more valuable as the strike price increases. Figure 12-1a–d illustrate the way in which put and call prices depend on the stock price and strike price.

Time to Expiration

Now consider the effect of the expiration date. Both put and call American options become more valuable (or at least do not decrease in value) as the time to expiration

TABLE 12-1 Summary of the Effect on the Price of a Stock Option of Increasing One Variable While Keeping All Others Fixed

Variable	European Call	European Put	American Call	American Put
Current stock price	+	−	+	−
Strike price	−	+	−	+
Time to expiration	?	?	+	+
Volatility	+	+	+	+
Risk-free rate	+	−	+	−
Amount of future dividends	−	+	−	+

+ indicates that an increase in the variable causes the option price to increase or stay the same;
− indicates that an increase in the variable causes the option price to decrease or stay the same;
? indicates that the relationship is uncertain.

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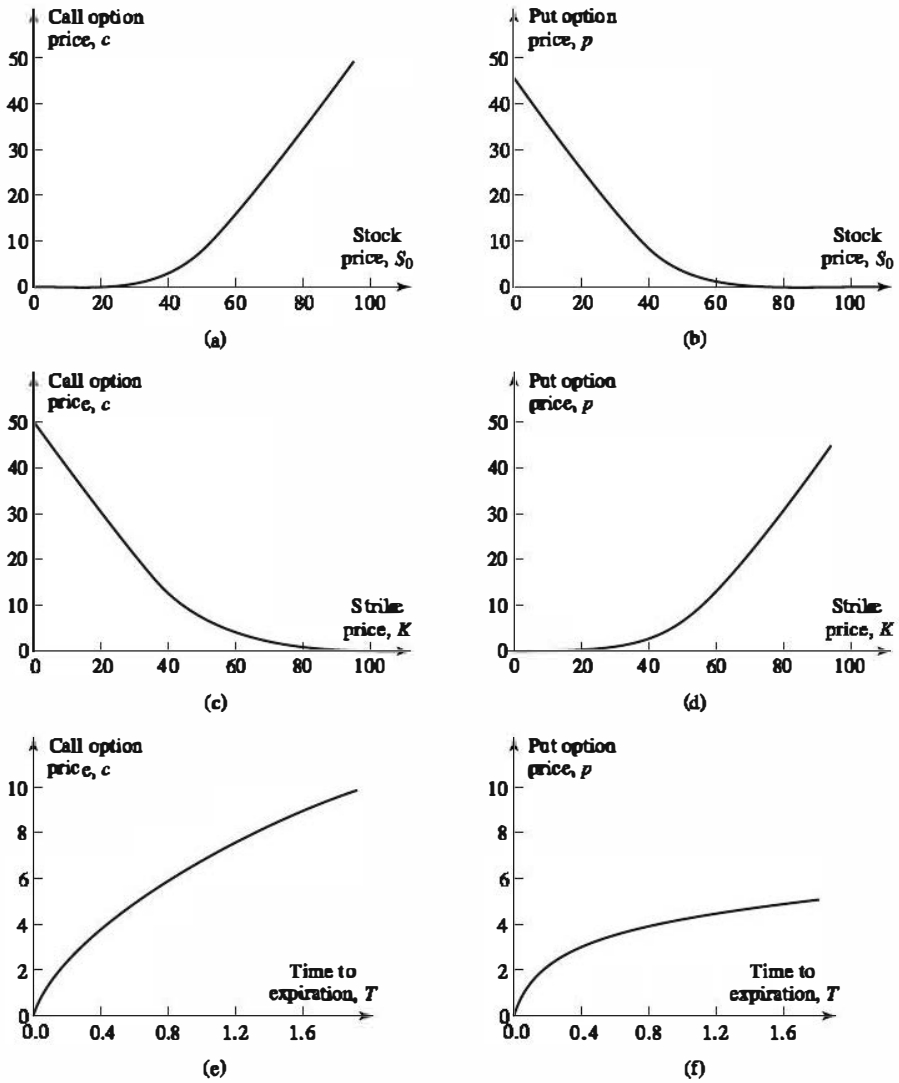

FIGURE 12-1 Effect of changes in stock price, strike price, and expiration date on option prices when $S_0 = 50$, $K = 50$, $r = 5\%$, $\sigma = 30\%$, and $T = 1$.

increases. Consider two American options that differ only as far as the expiration date is concerned. The owner of the long-life option has all the exercise opportunities open to the owner of the short-life option—and more. The long-life option must therefore always be worth at least as much as the short-life option.

Although European put and call options usually become more valuable as the time to expiration increases (see Figure 12-1e, f), this is not always the case. Consider two European call options on a stock: one with an expiration date in 1 month, the other with an expiration date in 2 months. Suppose that a very large dividend is expected in 6 weeks. The dividend will cause the stock price to decline, so that the short-life option could be worth more than the long-life option.[1]

[1] We assume that, when the life of the option is changed, the dividends on the stock and their timing remain unchanged.

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Volatility

Roughly speaking, the *volatility* of a stock price is a measure of how uncertain we are about future stock price movements. As volatility increases, the chance that the stock will do very well or very poorly increases. For the owner of a stock, these two outcomes tend to offset each other. However, this is not so for the owner of a call or put. The owner of a call benefits from price increases but has limited downside risk in the event of price decreases because the most the owner can lose is the price of the option. Similarly, the owner of a put benefits from price decreases, but has limited downside risk in the event of price increases. The values of both calls and puts therefore increase as volatility increases (see Figure 12-2a, b).

Risk-Free Interest Rate

The risk-free interest rate affects the price of an option in a less clear-cut way. As interest rates in the economy increase, the expected return required by investors from the stock tends to increase. In addition, the present value of any future cash flow received by the holder of the option decreases. The combined impact of these two effects is to increase the value of call options and decrease the value of put options (see Figure 12-2c, d).

It is important to emphasize that we are assuming that interest rates change while all other variables stay the same. In particular we are assuming in Table 12-1 that interest rates change while the stock price remains the same. In practice, when interest rates rise (fall), stock prices tend to fall (rise). The combined effect of an interest rate increase and the accompanying stock price decrease can be to decrease the value of a call option and increase the value of a put option. Similarly, the combined effect of an interest rate decrease and the accompanying stock price increase can be to increase the value of a call option and decrease the value of a put option.

Amount of Future Dividends

Dividends have the effect of reducing the stock price on the ex-dividend date. This is bad news for the value of call options and good news for the value of put options. Consider a dividend whose ex-dividend date is during the life of an option. The value of the option is negatively related to the size of the dividend if the option is a call and positively related to the size of the dividend if the option is a put.

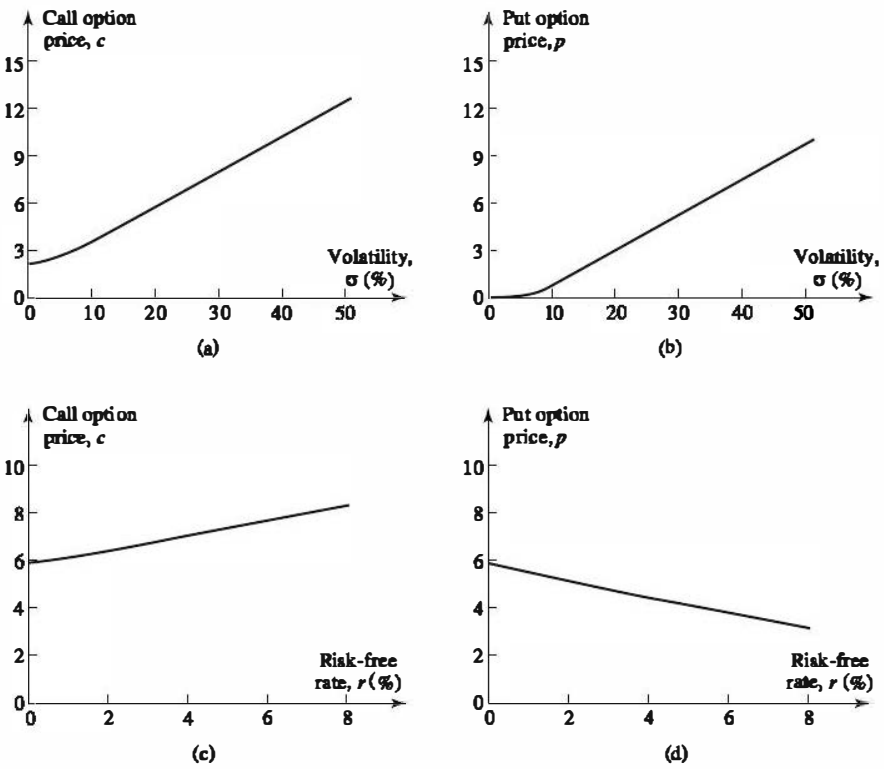

FIGURE 12-2 Effect of changes in volatility and risk-free interest rate on option prices when $S_0 = 50$, $K = 50$, $r = 5\%$, $\sigma = 30\%$, and $T = 1$.

ASSUMPTIONS AND NOTATION

In this chapter, we will make assumptions similar to those made when deriving forward and futures prices in Chapter B. We assume that there are some market participants, such as large investment banks, for which the following statements are true:

1. There are no transaction costs.
2. All trading profits (net of trading losses) are subject to the same tax rate.
3. Borrowing and lending are possible at the risk-free interest rate.

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We assume that these market participants are prepared to take advantage of arbitrage opportunities as they arise. As discussed in Chapters 4 and B, this means that any available arbitrage opportunities disappear very quickly. For the purposes of our analysis, it is therefore reasonable to assume that there are no arbitrage opportunities.

We will use the following notation:

- S_0: Current stock price
- K: Strike price of option
- T: Time to expiration of option
- S_T: Stock price on the expiration date
- r: Continuously compounded risk-free rate of interest for an investment maturing in time T
- C: Value of American call option to buy one share
- P: Value of American put option to sell one share
- c: Value of European call option to buy one share
- p: Value of European put option to sell one share

It should be noted that r is the nominal rate of interest, not the real rate of interest. We can assume that $r > 0$. Otherwise, a risk-free investment would provide no advantages over cash. (Indeed, if $r < 0$, cash would be preferable to a risk-free investment.)

UPPER AND LOWER BOUNDS FOR OPTION PRICES

In this section, we derive upper and lower bounds for option prices. These bounds do not depend on any particular assumptions about the factors mentioned earlier (except $r > 0$). If an option price is above the upper bound or below the lower bound, then there are profitable opportunities for arbitrageurs.

Upper Bounds

An American or European call option gives the holder the right to buy one share of a stock for a certain price. No matter what happens, the option can never be worth more than the stock. Hence, the stock price is an upper bound to the option price:

$$c \le S_0 \quad \text{and} \quad C \le S_0 \tag{12.1}$$

If these relationships were not true, an arbitrageur could easily make a riskless profit by buying the stock and selling the call option.

An American put option gives the holder the right to sell one share of a stock for K. No matter how low the stock price becomes, the option can never be worth more than K. Hence,

$$P \le K \tag{12.2}$$

For European options, we know that at maturity the option cannot be worth more than K. It follows that it cannot be worth more than the present value of K today:

$$p \le Ke^{-rT} \tag{12.3}$$

If this were not true, an arbitrageur could make a riskless profit by writing the option and investing the proceeds of the sale at the risk-free interest rate.

Lower Bound for Calls on Non-Dividend-Paying Stocks

A lower bound for the price of a European call option on a non-dividend-paying stock is

$$S_0 - Ke^{-rT}$$

We first look at a numerical example and then consider a more formal argument.

Suppose that $S_0 = \$20$, $K = \$18$, $r = 10\%$ per annum, and $T = 1$ year. In this case,

$$S_0 - Ke^{-rT} = 20 - 18e^{-0.1} = 3.71$$

or \$3.71. Consider the situation where the European call price is \$3.00, which is less than the theoretical minimum of \$3.71. An arbitrageur can short the stock and buy the call to provide a cash inflow of \$20.00 − \$3.00 = \$17.00. If invested for 1 year at 10% per annum, the \$17.00 grows to $17e^{0.1} = \$18.79$. At the end of the year, the option expires. If the stock price is greater than \$18.00, the arbitrageur exercises the option for \$18.00, closes out the short position, and makes a profit of

$$\$18.79 - \$18.00 = \$0.79$$

If the stock price is less than \$18.00, the stock is bought in the market and the short position is closed out. The arbitrageur then makes an even greater profit. For example, if the stock price is \$17.00, the arbitrageur's profit is

$$\$18.79 - \$17.00 = \$1.79$$

For a more formal argument, we consider the following two portfolios:

Portfolio A: one European call option plus a zero-coupon bond that provides a payoff of K at time T

Portfolio B: one share of the stock.

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In portfolio A, the zero-coupon bond will be worth K at time T. If $S_T > K$, the call option is exercised at maturity and portfolio A is worth S_T. If $S_T < K$, the call option expires worthless and the portfolio is worth K. Hence, at time T, portfolio A is worth

$$\max(S_T, K)$$

Portfolio B is worth S_T at time T. Hence, portfolio A is always worth as much as, and can be worth more than, portfolio B at the option's maturity. It follows that in the absence of arbitrage opportunities this must also be true today. The zero-coupon bond is worth Ke^{-rT} today. Hence,

$$c + Ke^{-rT} \geq S_0$$

or

$$c \geq S_0 - Ke^{-rT}$$

Because the worst that can happen to a call option is that it expires worthless, its value cannot be negative. This means that $c \geq 0$ and therefore

$$c \geq \max(S_0 - Ke^{-rT}, 0) \quad (12.4)$$

Example 12.1

Consider a European call option on a non-dividend-paying stock when the stock price is \$51, the strike price is \$50, the time to maturity is 6 months, and the risk-free interest rate is 12% per annum. In this case, $S_0 = 51$, $K = 50$, $T = 0.5$, and $r = 0.12$. From Equation (12.4), a lower bound for the option price is $S_0 - Ke^{-rT}$, or

$$51 - 50e^{-0.12\times0.5} = \$3.91$$

Lower Bound for European Puts on Non-Dividend-Paying Stocks

For a European put option on a non-dividend-paying stock, a lower bound for the price is

$$Ke^{-rT} - S_0$$

Again, we first consider a numerical example and then look at a more formal argument.

Suppose that $S_0 = \$37$, $K = \$40$, $r = 5\%$ per annum, and $T = 0.5$ years. In this case,

$$Ke^{-rT} - S_0 = 40e^{-0.05\times0.5} - 37 = \$2.01$$

Consider the situation where the European put price is \$1.00, which is less than the theoretical minimum of \$2.01. An arbitrageur can borrow \$38.00 for 6 months to buy both the put and the stock. At the end of the 6 months, the arbitrageur will be required to repay $38e^{0.05\times0.5} = \$38.96$. If the stock price is below \$40.00, the arbitrageur exercises the option to sell the stock for \$40.00, repays the loan, and makes a profit of

$$\$40.00 - \$38.96 = \$1.04$$

If the stock price is greater than \$40.00, the arbitrageur discards the option, sells the stock, and repays the loan for an even greater profit. For example, if the stock price is \$42.00, the arbitrageur's profit is

$$\$42.00 - \$38.96 = \$3.04$$

For a more formal argument, we consider the following two portfolios:

Portfolio C: one European put option plus one share

Portfolio D: a zero-coupon bond paying off K at time T.

If $S_T < K$, then the option in portfolio C is exercised at option maturity and the portfolio becomes worth K. If $S_T > K$, then the put option expires worthless and the portfolio is worth S_T at this time. Hence, portfolio C is worth

$$\max(S_T, K)$$

in time T. Portfolio D is worth K in time T. Hence, portfolio C is always worth as much as, and can sometimes be worth more than, portfolio D in time T. It follows that in the absence of arbitrage opportunities portfolio C must be worth at least as much as portfolio D today. Hence,

$$p + S_0 \geq Ke^{-rT}$$

or

$$p \geq Ke^{-rT} - S_0$$

Because the worst that can happen to a put option is that it expires worthless, its value cannot be negative. This means that

$$p \geq \max(Ke^{-rT} - S_0, 0) \quad (12.5)$$

Example 12.2

Consider a European put option on a non-dividend-paying stock when the stock price is \$38, the strike price is \$40, the time to maturity is 3 months, and the risk-free rate of interest is 10% per annum. In this case $S_0 = 38$, $K = 40$, $T = 0.25$, and $r = 0.10$. From Equation (12.5), a lower bound for the option price is $Ke^{-rT} - S_0$, or

$$40e^{-0.1\times0.25} - 38 = \$1.01$$

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PUT-CALL PARITY

We now derive an important relationship between the prices of European put and call options that have the same strike price and time to maturity. Consider the following two portfolios that were used in the previous section:

Portfolio A: one European call option plus a zero-coupon bond that provides a payoff of K at time T

Portfolio C: one European put option plus one share of the stock.

We continue to assume that the stock pays no dividends. The call and put options have the same strike price K and the same time to maturity T.

As discussed in the previous section, the zero-coupon bond in portfolio A will be worth K at time T. If the stock price S_T at time T proves to be above K, then the call option in portfolio A will be exercised. This means that portfolio A is worth $(S_T - K) + K = S_T$ at time T in these circumstances. If S_T proves to be less than K, then the call option in portfolio A will expire worthless and the portfolio will be worth K at time T.

In portfolio C, the share will be worth S_T at time T. If S_T proves to be below K, then the put option in portfolio C will be exercised. This means that portfolio C is worth $(K - S_T) + S_T = K$ at time T in these circumstances. If S_T proves to be greater than K, then the put option in portfolio C will expire worthless and the portfolio will be worth S_T at time T.

The situation is summarized in Table 12-2. If $S_T > K$, both portfolios are worth S_T at time T; if $S_T < K$, both portfolios are worth K at time T. In other words, both are worth

$$\max(S_T, K)$$

when the options expire at time T. Because they are European, the options cannot be exercised prior to time T. Since the portfolios have identical values at time T, they must have identical values today. If this were not the case, an arbitrageur could buy the less expensive portfolio and sell the more expensive one. Because the portfolios are guaranteed to cancel each other out at time T, this trading strategy would lock in an arbitrage profit equal to the difference in the values of the two portfolios.

The components of portfolio A are worth c and Ke^{-rT} today, and the components of portfolio C are worth p and S_0 today. Hence,

TABLE 12-2 Values of Portfolio A and Portfolio C at Time T

		$S_T > K$	$S_T < K$
Portfolio A	Call option	$S_T - K$	0
	Zero-coupon bond	K	K
	Total	S_T	K
Portfolio C	Put Option	0	$K - S_T$
	Share	S_T	S_T
	Total	S_T	K

$$c + Ke^{-rT} = p + S_0 \tag{12.8}$$

This relationship is known as *put-call parity*. It shows that the value of a European call with a certain exercise price and exercise date can be deduced from the value of a European put with the same exercise price and exercise date, and vice versa.

To illustrate the arbitrage opportunities when Equation (12.6) does not hold, suppose that the stock price is \$31, the exercise price is \$30, the risk-free interest rate is 10% per annum, the price of a three-month European call option is \$3, and the price of a 3-month European put option is \$2.25. In this case,

$$c + Ke^{-rT} = 3 + 30e^{-0.1\times 3/12} = \$32.26$$
$$p + S_0 = 2.25 + 31 = \$33.25$$

Portfolio C is overpriced relative to portfolio A. An arbitrageur can buy the securities in portfolio A and short the securities in portfolio C. The strategy involves buying the call and shorting both the put and the stock, generating a positive cash flow of

$$-3 + 2.25 + 31 = \$30.25$$

up front. When invested at the risk-free interest rate, this amount grows to

$$30.25e^{0.1\times 0.25} = \$31.02$$

in three months. If the stock price at expiration of the option is greater than \$30, the call will be exercised. If it is less than \$30, the put will be exercised. In either case, the arbitrageur ends up buying one share for \$30. This share can be used to close out the short position. The net profit is therefore

$$\$31.02 - \$30.00 = \$1.02$$

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For an alternative situation, suppose that the call price is \$3 and the put price is \$1. In this case,

$$c + Ke^{-rT} = 3 + 30e^{-0.1\times3/12} = \$32.26$$
$$p + S_0 = 1 + 31 = \$32.00$$

Portfolio A is overpriced relative to portfolio C. An arbitrageur can short the securities in portfolio A and buy the securities in portfolio C to lock in a profit. The strategy involves shorting the call and buying both the put and the stock with an initial investment of

$$\$31 + \$1 - \$3 = \$29$$

When the investment is financed at the risk-free interest rate, a repayment of $29e^{0.1\times0.25} = \$29.73$ is required at the end of the three months. As in the previous case, either the call or the put will be exercised. The short call and long put option position therefore leads to the stock being sold for \$30.00. The net profit is therefore

$$\$30.00 - \$29.73 = \$0.27$$

These examples are illustrated in Table 12-3. Box 12-1 shows how options and put-call parity can help us understand the positions of the debt holders and equity holders in a company.

American Options

Put-call parity holds only for European options. However, it is possible to derive some results for American option prices. It can be shown that, when there are no dividends,

$$S_0 - K \le C - P \le S_0 - Ke^{-rT} \qquad (12.7)$$

Example 12.3

An American call option on a non-dividend-paying stock with strike price \$20.00 and maturity in 5 months is worth \$1.50. Suppose that the current stock price is \$19.00 and the risk-free interest rate is 10% per annum. From Equation (12.7), we have

$$19 - 20 \le C - P \le 19 - 20e^{-0.1\times5/12}$$

or

$$1 \ge P - C \ge 0.18$$

showing that $P - C$ lies between \$1.00 and \$0.18. With C at \$1.50, P must lie between \$1.68 and \$2.50. In other words, upper and lower bounds for the price of an American put with the same strike price and expiration date as the American call are \$2.50 and \$1.68.

TABLE 12-3 Arbitrage Opportunities When Put-Call Parity Does Not Hold. Stock price = \$31; interest rate = 10%; call price = \$3. Both put and call have strike price of \$30 and three months to maturity.

Three-Month Put Price = \$2.25	Three-Month Put Price = \$1
Action now: Buy call for \$3 Short put to realize \$2.25 Short the stock to realize \$31 Invest \$30.25 for 3 months	*Action now*: Borrow \$29 for 3 months Short call to realize \$3 Buy put for \$1 Buy the stock for \$31
Action in 3 months if $S_T > 30$: Receive \$31.02 from investment Exercise call to buy stock for \$30 Net profit = \$1.02	*Action in 3 months if $S_T > 30$*: Call exercised: sell stock for \$30 Use \$29.73 to repay loan Net profit = \$0.27
Action in 3 months if $S_T < 30$: Receive \$31.02 from investment Put exercised: buy stock for \$30 Net profit = \$1.02	*Action in .3 months if $S_T < 30$*: Exercise put to sell stock for \$30 Use \$29.73 to repay loan Net profit = \$0.27

CALLS ON A NON-DIVIDEND-PAYING STOCK

In this section, we first show that it is never optimal to exercise an American call option on a non-dividend-paying stock before the expiration date.

To illustrate the general nature of the argument, consider an American call option on a non-dividend-paying stock with one month to expiration when the stock price is \$70 and the strike price is \$40. The option is deep in the money, and the investor who owns the option might well be tempted to exercise it immediately. However, if the investor plans to hold the stock obtained by exercising the option for more than one month, this is not the best strategy. A better course of action is to keep the option and exercise it at the end of the month. The \$40 strike

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BOX 12-1 Put-Call Parity and Capital Structure

Fischer Black, Myron Scholes, and Robert Merton were the pioneers of option pricing. In the early 1970s, they also showed that options can be used to characterize the capital structure of a company. Today this analysis is widely used by financial institutions to assess a company's credit risk.

To illustrate the analysis, consider a company that has assets that are financed with zero-coupon bonds and equity. Suppose that the bonds mature in five years at which time a principal payment of K is required. The company pays no dividends. If the assets are worth more than K in five years, the equity holders choose to repay the bond holders. If the assets are worth less than K, the equity holders choose to declare bankruptcy and the bond holders end up owning the company.

The value of the equity in five years is therefore $\max(A_T - K, 0)$; where A_T is the value of the company's assets at that time. This shows that the equity holders have a five-year European call option on the assets of the company with a strike price of K. What about the bondholders? They get $\min(A_T, K)$ in five years. This is the same as $K - \max(K - A_T, 0)$. This shows that today the bonds are worth the present value of K minus the value of a five-year European put option on the assets with a strike price of K.

To summarize, if c and p are the values, respectively, of the call and put options on the company's assets, then

$$\text{Value of company's equity} = c$$

$$\text{Value of company's debt} = PV(K) - p$$

Denote the value of the assets of the company today by A_0. The value of the assets must equal the total value of the instruments used to finance the assets. This means that it must equal the sum of the value of the equity and the value of the debt, so that

$$A_0 = c + \left[PV(K) - p\right]$$

Rearranging this equation, we have

$$c + PV(K) = p + A_0$$

This is the put-call parity result in Equation (12.6) for call and put options on the assets of the company.

price is then paid out one month later than it would be if the option were exercised immediately, so that interest is earned on the $40 for one month. Because the stock pays no dividends, no income from the stock is sacrificed. A further advantage of waiting rather than exercising immediately is that there is some chance (however remote) that the stock price will fall below $40 in one month. In this case the investor will not exercise in one month and will be glad that the decision to exercise early was not taken!

This argument shows that there are no advantages to exercising early if the investor plans to keep the stock for the remaining life of the option (one month, in this case). What if the investor thinks the stock is currently overpriced and is wondering whether to exercise the option and sell the stock? In this case, the investor is better off selling the option than exercising it.[2] The option will be bought by another investor who does want to hold the stock. Such investors must exist. Otherwise the current stock price would not be $70. The price obtained for the option will be greater than its intrinsic value of $30, for the reasons mentioned earlier.

For a more formal argument, we can use Equation (12.4):

$$c \geq S_0 - Ke^{-rT}$$

Because the owner of an American call has all the exercise opportunities open to the owner of the corresponding European call, we must have $C \geq c$. Hence,

$$C \geq S_0 - Ke^{-rT}$$

Given $r > 0$, it follows that $C > S_0 - K$ when $T > 0$. This means that C is always greater than the option's intrinsic value prior to maturity. If it were optimal to exercise at a particular time prior to maturity, C would equal the option's intrinsic value at that time. It follows that it can never be optimal to exercise early.

To summarize, there are two reasons an American call on a non-dividend-paying stock should not be exercised early. One relates to the insurance that it provides. A call option, when held instead of the stock itself, in effect insures the holder against the stock price falling below the strike price. Once the option has been exercised and the strike price has been exchanged for the stock price, this insurance vanishes. The other reason concerns the time value of money. From the perspective of the option holder, the later the strike price is paid out the better.

Bounds

Because American call options are never exercised early when there are no dividends, they are equivalent to

[2] As an alternative strategy, the investor can keep the option and short the stock to lock in a better profit than $30.

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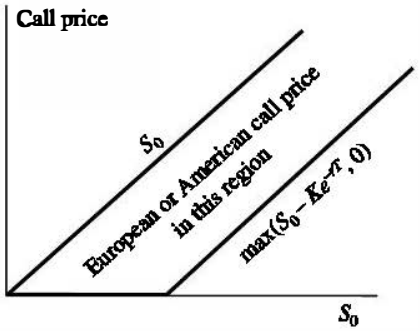

FIGURE 12-3 Bounds for European and American call options when there are no dividends.

European call options, so that $C = c$. From Equations (12.1) and (12.4), it follows that lower and upper bounds are given by

$$\max(S_0 - Ke^{-rT}, 0) \quad \text{and} \quad S_0$$

respectively. These bounds are illustrated in Figure 12-3.

The general way in which the call price varies with the stock price, S_0, is shown in Figure 12-4. As r or T or the stock price volatility increases, the line relating the call price to the stock price moves in the direction indicated by the arrows.

PUTS ON A NON-DIVIDEND-PAYING STOCK

It can be optimal to exercise an American put option on a non-dividend-paying stock early. Indeed, at any given time during its life, the put option should always be exercised early if it is sufficiently deep in the money.

To illustrate, consider an extreme situation. Suppose that the strike price is \$10 and the stock price is virtually zero. By exercising immediately, an investor makes an immediate gain of \$10. If the investor waits, the gain from exercise might be less than \$10, but it cannot be more than \$10, because negative stock prices are impossible. Furthermore, receiving \$10 now is preferable to receiving \$10 in the future. It follows that the option should be exercised immediately.

Like a call option, a put option can be viewed as providing insurance. A put option, when held in conjunction with the stock, insures the holder against the stock price falling below a certain level. However, a put option is different from a call option in that it may be optimal for an investor to forgo this insurance and exercise early in order to realize the strike price immediately. In general, the early exercise of a put option becomes more attractive as S_0 decreases, as r increases, and as the volatility decreases.

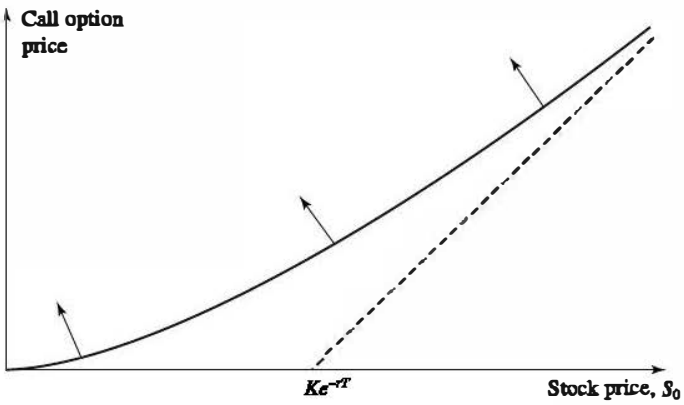

FIGURE 12-4 Variation of price of an American or European call option on a non-dividend-paying stock with the stock price. Curve moves in the direction of the arrows when there is an increase in the interest rate, time to maturity, or stock price volatility.

Bounds

From Equations (12.3) and (12.5), lower and upper bounds for a European put option when there are no dividends are given by

$$\max\left(Ke^{-rT} - S_0, 0\right) \le p \le Ke^{-rT}$$

For an American put option on a non-dividend-paying stock, the condition

$$P \ge \max\left(K - S_0, 0\right)$$

must apply because the option can be exercised at any time. This is a stronger condition than the one for a European put option in Equation (12.5). Using the result in Equation (12.2), bounds for an American put option on a non-dividend-paying stock are

$$\max\left(K - S_0, 0\right) \le P \le K$$

Figure 12-5 illustrates the bounds.

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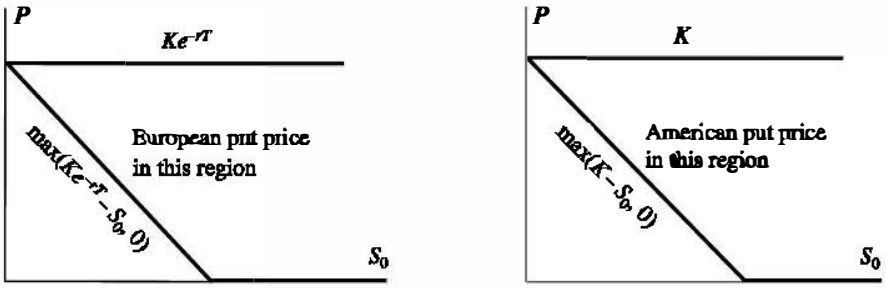

FIGURE 12-5 Bounds for European and American put options when there are no dividends.

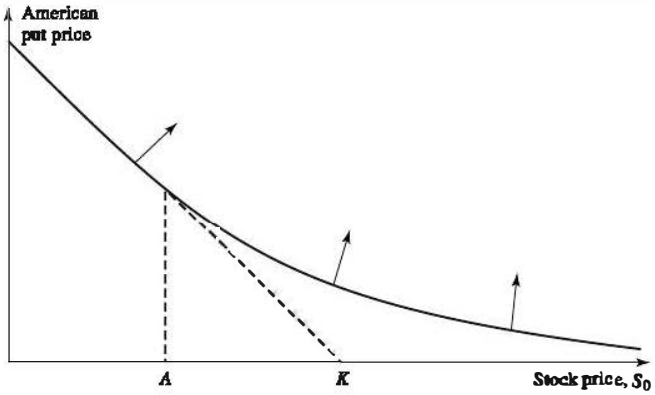

FIGURE 12-6 Variation of price of an American put option with stock price. Curve moves in the direction of the arrows when the time to maturity or stock price volatility increases or when the interest rate decreases.

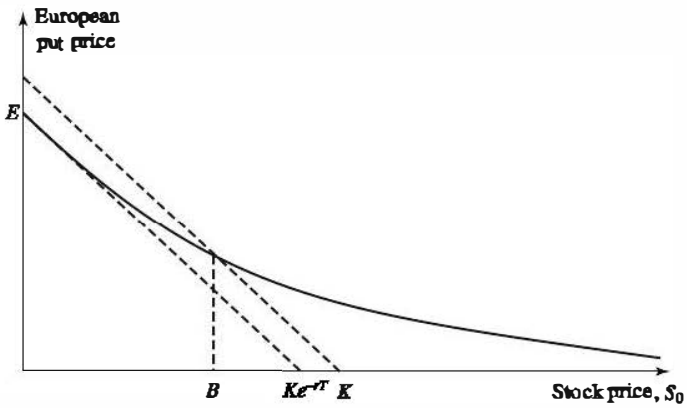

FIGURE 12-7 Variation of price of a European put option with the stock price.

Figure 12-6 shows the general way in which the price of an American put option varies with S_0. As we argued earlier, provided that $r > 0$, it is always optimal to exercise an American put immediately when the stock price is sufficiently low. When early exercise is optimal, the value of the option is $K - S_0$. The curve representing the value of the put therefore merges into the put's intrinsic value, $K - S_0$, for a sufficiently small value of S_0. In Figure 12-6, this value of S_0 is shown as point A. The line relating the put price to the stock price moves in the direction indicated by the arrows when r decreases, when the volatility increases, and when T increases.

Because there are some circumstances when it is desirable to exercise an American put option early, it follows that an American put option is always worth more than the corresponding European put option. Furthermore, because an American put is sometimes worth its intrinsic value (see Figure 12-6), it follows that a European put option must sometimes be worth less than its intrinsic value. This means that the curve representing the relationship between the put price and the stock price for a European option must be below the corresponding curve for an American option.

Figure 12-7 shows the variation of the European put price with the stock price. Note that point B in Figure 12-7, at which the price of the option is equal to its intrinsic value, must represent a higher value of the stock price than point A in Figure 12-6 because the curve in Figure 12-7 is below that in Figure 12-6. Point E in Figure 12-7 is where $S_0 = 0$ and the European put price is Ke^{-rT}.

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EFFECT OF DIVIDENDS

The results produced so far in this chapter have assumed that we are dealing with options on a non-dividend-paying stock. In this section, we examine the impact of dividends. We assume that the dividends that will be paid during the life of the option are known. Most exchange-traded stock options have a life of less than one year, so this assumption is often not too unreasonable. We will use D to denote the present value of the dividends during the life of the option. In the calculation of D, a dividend is assumed to occur at the time of its ex-dividend date.

Lower Bound for Calls and Puts

We can redefine portfolios A and B as follows:

Portfolio A: one European call option plus an amount of cash equal to $D + Ke^{-rT}$

Portfolio B: one share

A similar argument to the one used to derive Equation (12.4) shows that

$$c \geq \max\left(S_0 - D - Ke^{-rT}, 0\right) \tag{12.8}$$

We can also redefine portfolios C and D as follows:

Portfolio C: one European put option plus one share

Portfolio D: an amount of cash equal to $D + Ke^{-rT}$

A similar argument to the one used to derive Equation (12.5) shows that

$$P \geq \max\left(D + Ke^{-rT} - S_0, 0\right) \tag{12.9}$$

Early Exercise

When dividends are expected, we can no longer assert that an American call option will not be exercised early. Sometimes it is optimal to exercise an American call immediately prior to an ex-dividend date. It is never optimal to exercise a call at other times.

Put–Call Parity

Comparing the value at option maturity of the redefined portfolios A and C shows that, with dividends, the put–call parity result in Equation (12.6) becomes

$$c + D + Ke^{-rT} = p + S_0 \tag{12.10}$$

Dividends cause Equation (12.7) to be modified to

$$S_0 - D - K \leq C - P \leq S_0 - Ke^{-rT} \tag{12.11}$$

SUMMARY

There are six factors affecting the value of a stock option: the current stock price, the strike price, the expiration date, the stock price volatility, the risk-free interest rate, and the dividends expected during the life of the option. The value of a call usually increases as the current stock price, the time to expiration, the volatility, and the risk-free interest rate increase. The value of a call decreases as the strike price and expected dividends increase. The value of a put usually increases as the strike price, the time to expiration, the volatility, and the expected dividends increase. The value of a put decreases as the current stock price and the risk-free interest rate increase.

It is possible to reach some conclusions about the value of stock options without making any assumptions about the volatility of stock prices. For example, the price of a call option on a stock must always be worth less than the price of the stock itself. Similarly, the price of a put option on a stock must always be worth less than the option's strike price.

A European call option on a non-dividend-paying stock must be worth more than

$$\max\left(S_0 - Ke^{-rT}, 0\right)$$

where S_0 is the stock price, K is the strike price, r is the risk-free interest rate, and T is the time to expiration. A European put option on a non-dividend-paying stock must be worth more than

$$\max\left(Ke^{-rT} - S_0, 0\right)$$

When dividends with present value D will be paid, the lower bound for a European call option becomes

$$\max\left(S_0 - D - Ke^{-rT}, 0\right)$$

and the lower bound for a European put option becomes

$$\max\left(Ke^{-rT} + D - S_0, 0\right)$$

Put–call parity is a relationship between the price, c, of a European call option on a stock and the price, p, of a European put option on a stock. For a non-dividend-paying stock, it is

$$c + Ke^{-rT} = p + S_0$$

For a dividend-paying stock, the put–call parity relationship is

$$c + D + Ke^{-rT} = p + S_0$$

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Put–call parity does not hold for American options. However, it is possible to use arbitrage arguments to obtain upper and lower bounds for the difference between the price of an American call and the price of an American put.

Further Reading

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Trading Strategies Involving Options

13

Learning Objectives

After completing this reading you should be able to:

- Explain the motivation to initiate a covered call or a protective put strategy.
- Describe the use and calculate the payoffs of various spread strategies.
- Describe the use and explain the payoff functions of combination strategies.

Excerpt is Chapter 12 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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We discussed the profit pattern from an investment in a single option in Chapter 11. In this chapter we look at what can be achieved when an option is traded in conjunction with other assets. In particular, we examine the properties of portfolios consisting of (a) an option and a zero-coupon bond, (b) an option and the asset underlying the option, and (c) two or more options on the same asset.

A natural question is why a trader would want the profit patterns discussed here. The answer is that the choices a trader makes depend on the trader's judgment about how prices will move and the trader's willingness to take risks. Principal-protected notes, discussed in the first section, appeal to individuals who are risk-averse. They do not want to risk losing their principal, but have an opinion about whether a particular asset will increase or decrease in value and are prepared to let the return on principal depend on whether they are right. If a trader is willing to take rather more risk than this, he or she could choose a bull or bear spread. Yet more risk would be taken with a straightforward long position in a call or put option.

Suppose that a trader feels there will be a big move in price of an asset, but does not know whether this will be up or down. There are a number of alternative trading strategies. A risk-averse trader might choose a reverse butterfly spread where there will be a small gain if the trader's hunch is correct and a small loss if it is not. A more aggressive investor might choose a straddle or strangle where potential gains and losses are larger.

Further trading strategies involving options are considered in later chapters. For example, Chapter 14 covers exotic options and what is known as static options replication.

PRINCIPAL-PROTECTED NOTES

Options are often used to create what are termed *principal-protected notes* for the retail market. These are products that appeal to conservative investors. The return earned by the investor depends on the performance of a stock, a stock index, or other risky asset, but the initial principal amount invested is not at risk. An example will illustrate how a simple principal-protected note can be created.

Example 13.1

Suppose that the 3-year interest rate is 6% with continuous compounding. This means that $1{,}000e^{-0.06\times 3} = \$835.27$ will grow to $1,000 in 3 years. The difference between $1,000 and $835.27 is $164.73. Suppose that a stock portfolio is worth $1,000 and provides a dividend yield of 1.5% per annum. Suppose further that a 3-year at-the-money European call option on the stock portfolio can be purchased for less than $164.73. (From DerivaGem, it can be verified that this will be the case if the volatility of the value of the portfolio is less than about 15%.) A bank can offer clients a $1,000 investment opportunity consisting of:

1. A 3-year zero-coupon bond with a principal of $1,000
2. A 3-year at-the-money European call option on the stock portfolio.

If the value of the portfolio increases the investor gets whatever $1,000 invested in the portfolio would have grown to. (This is because the zero-coupon bond pays off $1,000 and this equals the strike price of the option.) If the value of the portfolio goes down, the option has no value, but payoff from the zero-coupon bond ensures that the investor receives the original $1,000 principal invested.

The attraction of a principal-protected note is that an investor is able to take a risky position without risking any principal. The worst that can happen is that the investor loses the chance to earn interest, or other income such as dividends, on the initial investment for the life of the note.

There are many variations on the product we have described. An investor who thinks that the price of an asset will decline can buy a principal-protected note consisting of a zero-coupon bond plus a put option. The investor's payoff in 3 years is then $1,000 plus the payoff (if any) from the put option.

Is a principal-protected note a good deal from the retail investor's perspective? A bank will always build in a profit for itself when it creates a principal-protected note. This means that, in Example 13.1, the zero-coupon bond plus the call option will always cost the bank less than $1,000. In addition, investors are taking the risk that the bank will not be in a position to make the payoff on the principal-protected note at maturity. (Some retail investors lost money on principal-protected notes created by

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Lehman Brothers when it failed in 2008.) In some situations, therefore, an investor will be better off if he or she buys the underlying option in the usual way and invests the remaining principal in a risk-free investment. However, this is not always the case. The investor is likely to face wider bid-offer spreads on the option than the bank and is likely to earn lower interest rates than the bank. It is therefore possible that the bank can add value for the investor while making a profit itself.

Now let us look at the principal-protected notes from the perspective of the bank. The economic viability of the structure in Example 13.1 depends critically on the level of interest rates and the volatility of the portfolio. If the interest rate is 3% instead of 6%, the bank has only $1{,}000 - 1{,}000e^{-0.03\times3} = \$86.07$ with which to buy the call option. If interest rates are 6%, but the volatility is 25% instead of 15%, the price of the option would be about $221. In either of these circumstances, the product described in Example 13.1 cannot be profitably created by the bank. However, there are a number of ways the bank can still create a viable 3-year product. For example, the strike price of the option can be increased so that the value of the portfolio has to rise by, say, 15% before the investor makes a gain; the investor's return could be capped; the return of the investor could depend on the average price of the asset instead of the final price; a knockout barrier could be specified. The derivatives involved in some of these alternatives will be discussed later in the book. (Capping the option corresponds to the creation of a bull spread for the investor and will be discussed later in this chapter.)

One way in which a bank can sometimes create a profitable principal-protected note when interest rates are low or volatilities are high is by increasing its life. Consider the situation in Example 13.1 when (a) the interest rate is 3% rather than 6% and (b) the stock portfolio has a volatility of 15% and provides a dividend yield of 1.5%. DerivaGem shows that a 3-year at-the-money European option costs about $119. This is more than the funds available to purchase it ($1{,}000 - 1{,}000e^{-0.03\times3} = \$86.07$). A 10-year at-the-money option costs about $217. This is less than the funds available to purchase it ($1{,}000 - 1{,}000e^{-0.03\times10} = \$259.18$), making the structure profitable. When the life is increased to 20 years, the option cost is about $281, which is much less than the funds available to purchase it ($1{,}000 - 1{,}000e^{-0.03\times20} = \$451.19$), so that the structure is even more profitable.

A critical variable for the bank in our example is the dividend yield. The higher it is, the more profitable the product is for the bank. If the dividend yield were zero, the principal-protected note in Example 13.1 cannot be profitable for the bank no matter how long it lasts. (This follows from Equation (12.4).)

TRADING AN OPTION AND THE UNDERLYING ASSET

For convenience, we will assume that the asset underlying the options considered in the rest of the chapter is a stock. (Similar trading strategies can be developed for other underlying assets.) We will also follow the usual practice of calculating the profit from a trading strategy as the final payoff minus the initial cost without any discounting.

There are a number of different trading strategies involving a single option on a stock and the stock itself. The profits from these are illustrated in Figure 13-1. In this figure and in other figures throughout this chapter, the dashed line shows the relationship between profit and the stock price for the individual securities constituting the portfolio, whereas the solid line shows the relationship between profit and the stock price for the whole portfolio.

In Figure 13-1a, the portfolio consists of a long position in a stock plus a short position in a European call option. This is known as *writing a covered call*. The long stock position "covers" or protects the investor from the payoff on the short call that becomes necessary if there is a sharp rise in the stock price. In Figure 13-1b, a short position in a stock is combined with a long position in a call option. This is the reverse of writing a covered call. In Figure 13-1c, the investment strategy involves buying a European put option on a stock and the stock itself. This is referred to as a *protective put* strategy. In Figure 13-1d, a short position in a put option is combined with a short position in the stock. This is the reverse of a protective put.

The profit patterns in Figures 13-1a, b, c, d have the same general shape as the profit patterns discussed in Chapter 11 for short put, long put, long call, and short call, respectively. Put-call parity provides a way of understanding why this is so. From Chapter 12, the put-call parity relationship is

$$p + S_0 = c + Ke^{-rT} + D \tag{13.1}$$

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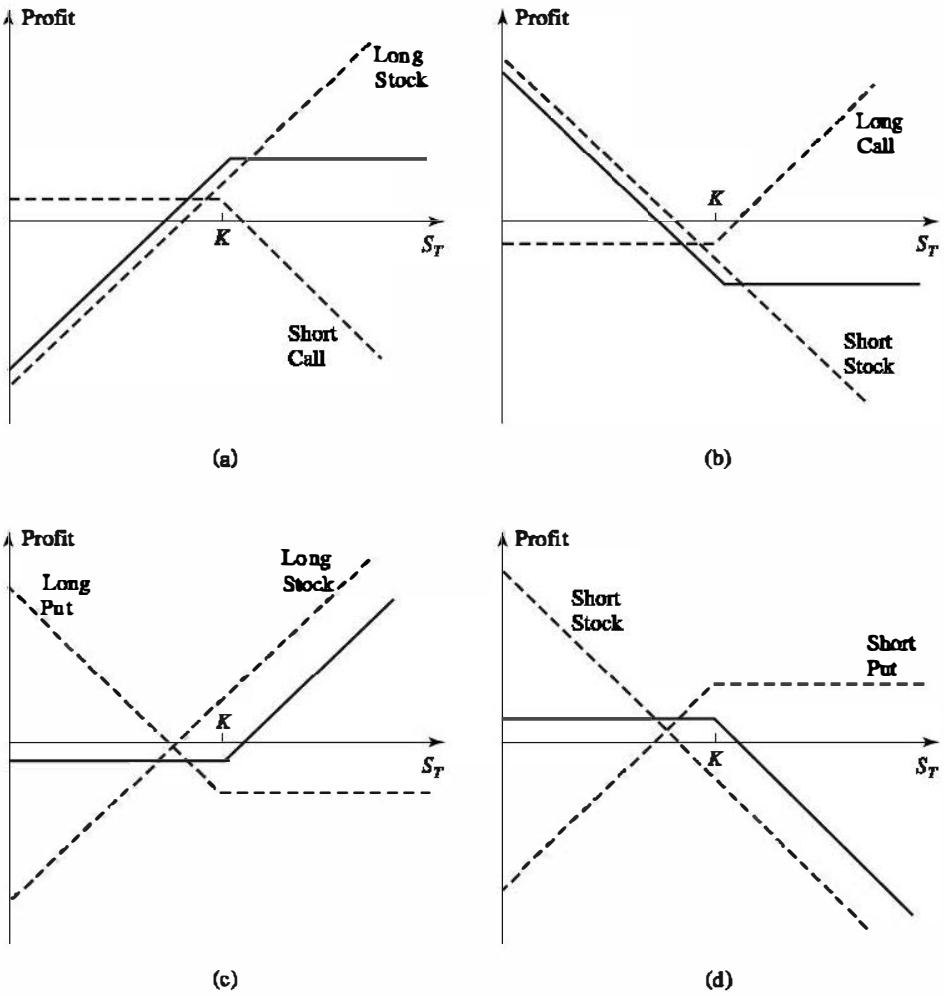

FIGURE 13-1 Profit patterns.

(a) long position in a stock combined with short position in a call; (b) short position in a stock combined with long position in a call; (c) long position in a put combined with long position in a stock; (d) short position in a put combined with short position in a stock.

where p is the price of a European put, S_0 is the stock price, c is the price of a European call, K is the strike price of both call and put, r is the risk-free interest rate, T is the time to maturity of both call and put, and D is the present value of the dividends anticipated during the life of the options.

Equation (13.1) shows that a long position in a European put combined with a long position in the stock is equivalent to a long European call position plus a certain amount ($= Ke^{-rT} + D$) of cash. This explains why the profit pattern in Figure 13-1c is similar to the profit pattern from a long call position. The position in Figure 13-1d is the reverse of that in Figure 13-1c and therefore leads to a profit pattern similar to that from a short call position.

Equation (13.1) can be rearranged to become

$$S_0 - c = Ke^{-rT} + D - p$$

This shows that a long position in a stock combined with a short position in a European call is equivalent to a short European put position plus a certain amount ($= Ke^{-rT} + D$) of cash. This equality explains why the profit pattern in Figure 13-1a is similar to the profit pattern from a short put position. The position in Figure 13-1b is the reverse of that in Figure 13-1a and therefore leads to a profit pattern similar to that from a long put position.

SPREADS

A spread trading strategy involves taking a position in two or more options of the same type (i.e., two or more calls or two or more puts).

Bull Spreads

One of the most popular types of spreads is a *bull spread*. This can be created by buying a European call option on a stock with a certain strike price and selling a European call option on the same stock with a higher strike price. Both options have the same expiration date. The strategy is illustrated in Figure 13-2. The profits from the two option positions taken separately are shown by the dashed lines. The profit from the whole strategy is the sum of the profits given by the dashed lines and is indicated by the solid line. Because a call price always decreases as the strike price increases, the value of the option sold is always less than the value of the option bought. A bull spread, when created from calls, therefore requires an initial investment.

Suppose that K_1 is the strike price of the call option bought, K_2 is the strike price of the call option sold, and S_T is the stock price on the expiration date of the options. Table 13-1 shows the total payoff that will be realized from a bull spread in different circumstances. If the stock price

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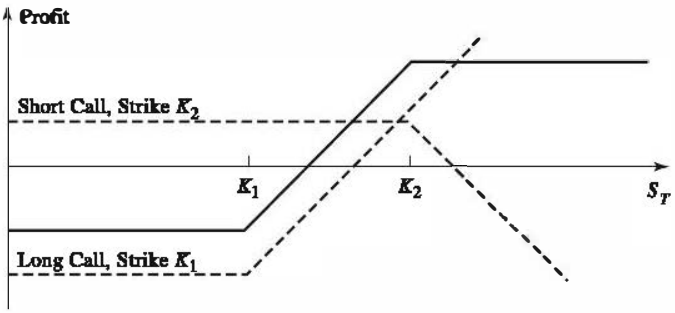

FIGURE 13-2 Profit from bull spread created using call options.

does well and is greater than the higher strike price, the payoff is the difference between the two strike prices, or $K_2 - K_1$. If the stock price on the expiration date lies between the two strike prices, the payoff is $S_T - K_1$. If the stock price on the expiration date is below the lower strike price, the payoff is zero. The profit in Figure 13-2 is calculated by subtracting the initial investment from the payoff.

A bull spread strategy limits the investor's upside as well as downside risk. The strategy can be described by saying that the investor has a call option with a strike price equal to K_1 and has chosen to give up some upside potential by selling a call option with strike price K_2 ($K_2 > K_1$). In return for giving up the upside potential, the investor gets the price of the option with strike price K_2. Three types of bull spreads can be distinguished:

1. Both calls are initially out of the money.
2. One call is initially in the money; the other call is initially out of the money.
3. Both calls are initially in the money.

The most aggressive bull spreads are those of type 1. They cost very little to set up and have a small probability of giving a relatively high payoff ($= K_2 - K_1$). As we move from type 1 to type 2 and from type 2 to type 3, the spreads become more conservative.

TABLE 13-1 Payoff from a Bull Spread Created Using Calls

Stock Price Range	Payoff from Long Call Option	Payoff from Short Call Option	Total Payoff
$S_T \le K_1$	0	0	0
$K_1 < S_T < K_2$	$S_T - K_1$	0	$S_T - K_1$
$S_T \ge K_2$	$S_T - K_1$	$-(S_T - K_2)$	$K_2 - K_1$

Example 13.2

An investor buys for \$3 a 3-month European call with a strike price of \$30 and sells for \$1 a 3-month European call with a strike price of \$35. The payoff from this bull spread strategy is \$5 if the stock price is above \$35, and zero if it is below \$30. If the stock price is between \$30 and \$35, the payoff is the amount by which the stock price exceeds \$30. The cost of the strategy is \$3 − \$1 = \$2. So the profit is:

Stock Price Range	Profit
$S_T \le 30$	−2
$30 < S_T < 35$	$S_T - 32$
$S_T \ge 35$	3

Bull spreads can also be created by buying a European put with a low strike price and selling a European put with a high strike price, as illustrated in Figure 13-3. Unlike bull spreads created from calls, those created from puts involve a positive up-front cash flow to the investor (ignoring margin requirements) and a payoff that is either negative or zero.

Bear Spreads

An investor who enters into a bull spread is hoping that the stock price will increase. By contrast, an investor who enters into a *bear spread* is hoping that the stock price

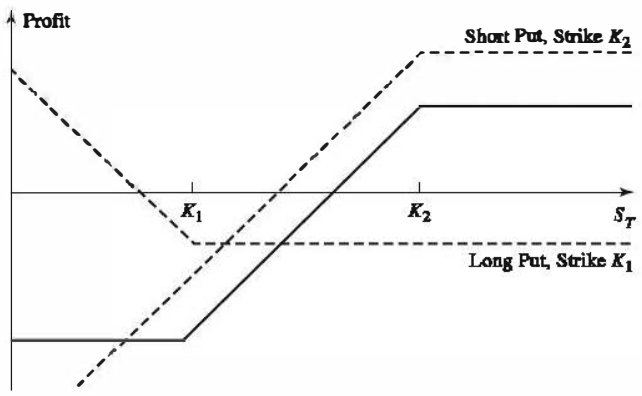

FIGURE 13-3 Profit from bull spread created using put options.

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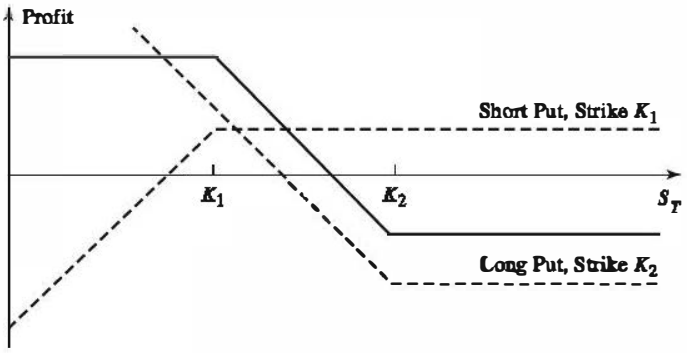

FIGURE 13-4 Profit from bear spread created using put options.

will decline. Bear spreads can be created by buying a European put with one strike price and selling a European put with another strike price. The strike price of the option purchased is greater than the strike price of the option sold. (This is in contrast to a bull spread, where the strike price of the option purchased is always less than the strike price of the option sold.) In Figure 13-4, the profit from the spread is shown by the solid line. A bear spread created from puts involves an initial cash outflow because the price of the put sold is less than the price of the put purchased. In essence, the investor has bought a put with a certain strike price and chosen to give up some of the profit potential by selling a put with a lower strike price. In return for the profit given up, the investor gets the price of the option sold.

Assume that the strike prices are K_1 and K_2, with $K_1 < K_2$. Table 13-2 shows the payoff that will be realized from a bear spread in different circumstances. If the stock price is greater than K_2, the payoff is zero. If the stock price is less than K_1, the payoff is $K_2 - K_T$. If the stock price is between K_1 and K_2, the payoff is $K_2 - S_T$. The profit is calculated by subtracting the initial cost from the payoff.

TABLE 13-2 Payoff from a Bear Spread Created with Put Options

Stock Price Range	Payoff from Long Put Option	Payoff from Short Put Option	Total Payoff
$S_T \le K_1$	$K_2 - S_T$	$-(K_1 - S_T)$	$K_2 - K_1$
$K_1 < S_T < K_2$	$K_2 - S_T$	0	$K_2 - S_T$
$S_T \ge K_2$	0	0	0

Example 13.3

An investor buys for \$3 a 3-month European put with a strike price of \$35 and sells for \$1 a 3-month European put with a strike price of \$30. The payoff from this bear spread strategy is zero if the stock price is above \$35, and \$5 if it is below \$30. If the stock price is between \$30 and \$35, the payoff is $35 - S_T$. The options cost \$3 − \$1 = \$2 up front. So the profit is:

Stock Price Range	Profit
$S_T \le 30$	+3
$30 < S_T < 35$	$33 - S_T$
$S_T \ge 35$	−2

Like bull spreads, bear spreads limit both the upside profit potential and the downside risk. Bear spreads can be created using calls instead of puts. The investor buys a call with a high strike price and sells a call with a low strike price, as illustrated in Figure 13-5. Bear spreads created with calls involve an initial cash inflow (ignoring margin requirements).

Box Spreads

A box spread is a combination of a bull call spread with strike prices K_1 and K_2 and a bear put spread with the same two strike prices. As shown in Table 13-3, the payoff from a box spread is always $K_2 - K_1$. The value of a box spread is therefore always the present value of this payoff

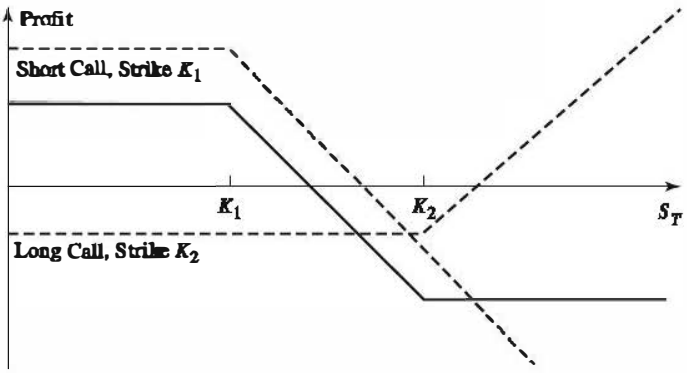

FIGURE 13-5 Profit from bear spread created using call options.

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TABLE 13-3 Payoff from a Box Spread

Stock Price Range	Payoff from Bull Call Spread	Payoff from Bear Put Spread	Total Payoff
$S_T \le K_1$	0	$K_2 - K_1$	$K_2 - K_1$
$K_1 < S_T < K_2$	$S_T - K_1$	$K_2 - S_T$	$K_2 - K_1$
$S_T \ge K_2$	$K_2 - K_1$	0	$K_2 - K_1$

or $(K_2 - K_1)e^{-rT}$. If it has a different value there is an arbitrage opportunity. If the market price of the box spread is too low, it is profitable to buy the box. This involves buying a call with strike price K_1, buying a put with strike price K_2, selling a call with strike price K_2, and selling a put with strike price K_1. If the market price of the box spread is too high, it is profitable to sell the box. This involves buying a call with strike price K_2, buying a put with strike price K_1, selling a call with strike price K_1, and selling a put with strike price K_2.

It is important to realize that a box-spread arbitrage only works with European options. Many of the options that trade on exchanges are American. As shown in Box 13-1, inexperienced traders who treat American options as European are liable to lose money.

Butterfly Spreads

A *butterfly spread* involves positions in options with three different strike prices. It can be created by buying a European call option with a relatively low strike price K_1, buying a European call option with a relatively high strike price K_3, and selling two European call options with a strike price K_2 that is halfway between K_1 and K_3. Generally, K_2 is close to the current stock price. The pattern of profits from the strategy is shown in Figure 13-6. A butterfly spread leads to a profit if the stock price stays close to K_2, but gives rise to a small loss if there is a significant stock price move in either direction. It is therefore an appropriate strategy for an investor who feels that large stock price moves are unlikely. The strategy requires a small investment initially. The payoff from a butterfly spread is shown in Table 13-4.

Suppose that a certain stock is currently worth $61. Consider an investor who feels that a significant price move in the next 6 months is unlikely. Suppose that the market prices of 6-month European calls are as follows:

Strike Price ($)	Call Price ($)
55	10
60	7
65	5

The investor could create a butterfly spread by buying one call with a $55 strike price, buying one call with a $65

BOX 13-1 Losing Money with Box Spreads

Suppose that a stock has a price of $50 and a volatility of 30%. No dividends are expected and the risk-free rate is 8%. A trader offers you the chance to sell on the CBOE a 2-month box spread where the strike prices are $55 and $60 for $5.10. Should you do the trade?

The trade certainly sounds attractive. In this case $K_1 = 55$, $K_2 = 60$, and the payoff is certain to be $5 in 2 months. By selling the box spread for $5.10 and investing the funds for 2 months you would have more than enough funds to meet the $5 payoff in 2 months. The theoretical value of the box spread today is $5 \times e^{-0.08\times 2/12} = \$4.93$.

Unfortunately there is a snag. CBOE stock options are American and the $5 payoff from the box spread is calculated on the assumption that the options comprising the box are European. Option prices for this example (calculated using DerivaGem) are shown in the table below. A bull call spread where the strike prices are $55 and $60 costs 0.96 − 0.26 = $0.70. (This is the same for both European and American options because, as we saw in Chapter 12, the price of a European call is the same as the price of an American call when there are no dividends.) A bear put spread with the same strike prices costs 9.46 − 5.23 = $4.23 if the options are European and 10.00 − 5.44 = $4.56 if they are American. The combined value of both spreads if they are created with European options is 0.70 + 4.23 = $4.93. This is the theoretical box spread price calculated above. The combined value of buying both spreads if they are American is 0.70 + 4.56 = $5.26. Selling a box spread created with American options for $5.10 would not be a good trade. You would realize this almost immediately as the trade involves selling a $60 strike put and this would be exercised against you almost as soon as you sold it!

Option Type	Strike Price	European Option Price	American Option Price
Call	60	0.26	0.26
Call	55	0.96	0.96
Put	60	9.46	10.00
Put	55	5.23	5.44

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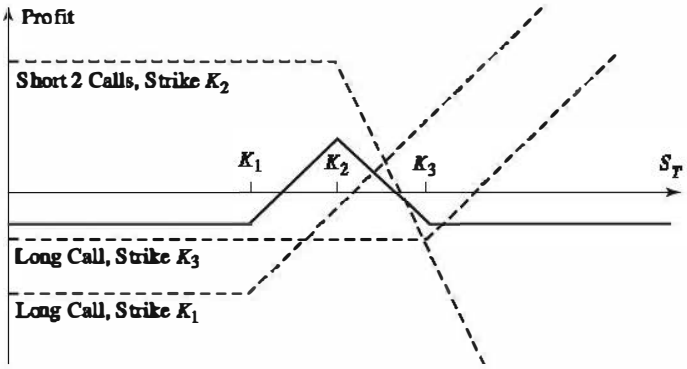

FIGURE 13-6 Profit from butterfly spread using call options.

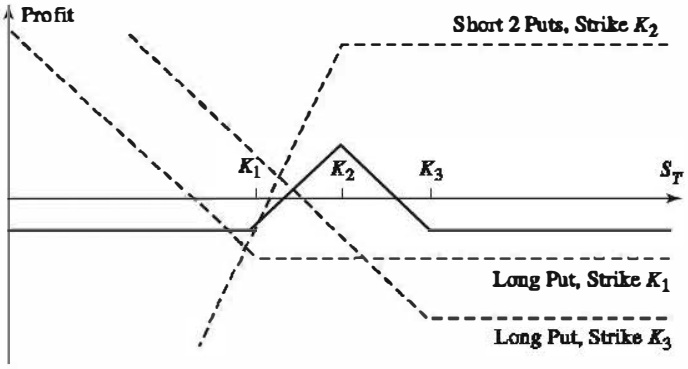

FIGURE 13-7 Profit from butterfly spread using put options.

TABLE 13-4 Payoff from a Butterfly Spread

Stock Price Range	Payoff from First Long Call	Payoff from Second Long Call	Payoff from Short Calls	Total Payoff*
$S_T \le K_1$	0	0	0	0
$K_1 < S_T \le K_2$	$S_T - K_1$	0	0	$S_T - K_1$
$K_2 < S_T < K_3$	$S_T - K_1$	0	$-2(S_T - K_2)$	$K_3 - S_T$
$S_T \ge K_3$	$S_T - K_1$	$S_T - K_3$	$-2(S_T - K_2)$	0

*These payoffs are calculated using the relationship $K_2 = 0.5(K_1 + K_3)$.

strike price, and selling two calls with a \$60 strike price. It costs \$10 + \$5 − (2 × \$7) = \$1 to create the spread. If the stock price in 6 months is greater than \$65 or less than \$55, the total payoff is zero, and the investor incurs a net loss of \$1. If the stock price is between \$56 and \$64, a profit is made. The maximum profit, \$4, occurs when the stock price in 6 months is \$60.

Butterfly spreads can be created using put options. The investor buys two European puts, one with a low strike price and one with a high strike price, and sells two European puts with an intermediate strike price, as illustrated in Figure 13-7. The butterfly spread in the example considered above would be created by buying one put with a strike price of \$55, another with a strike price of \$65, and selling two puts with a strike price of \$60. The use of put options results in exactly the same spread as the use of call options. Put-call parity can be used to show that the initial investment is the same in both cases.

A butterfly spread can be sold or shorted by following the reverse strategy. Options are sold with strike prices of K_1 and K_3, and two options with the middle strike price K_2 are purchased. This strategy produces a modest profit if there is a significant movement in the stock price.

Calendar Spreads

Up to now we have assumed that the options used to create a spread all expire at the same time. We now move on to *calendar spreads* in which the options have the same strike price and different expiration dates.

A calendar spread can be created by selling a European call option with a certain strike price and buying a longer-maturity European call option with the same strike price. The longer the maturity of an option, the more expensive it usually is. A calendar spread therefore usually requires an initial investment. Profit diagrams for calendar spreads are usually produced so that they show the profit when the short-maturity option expires on the assumption that the long-maturity option is closed out at that time. The profit pattern for a calendar spread produced from call options is shown in Figure 13-8. The pattern is similar to the profit from the butterfly spread in Figure 13-6. The investor makes a profit if the stock price at the expiration of the short-maturity option is close to the strike price of the short-maturity option. However, a loss is incurred when the stock price is significantly above or significantly below this strike price.

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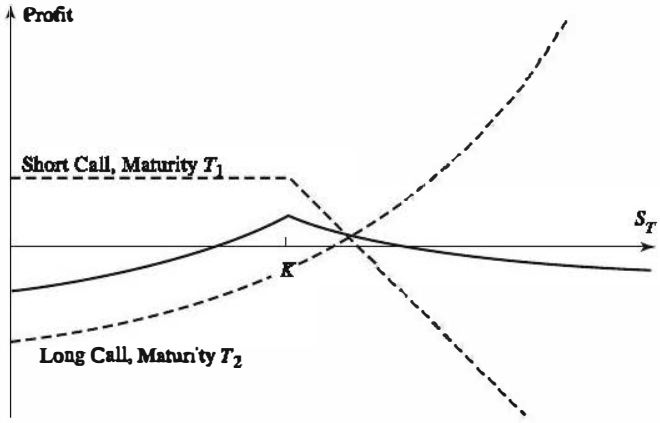

FIGURE 13-8 Profit from calendar spread created using two call options, calculated at the time when the short-maturity call option expires.

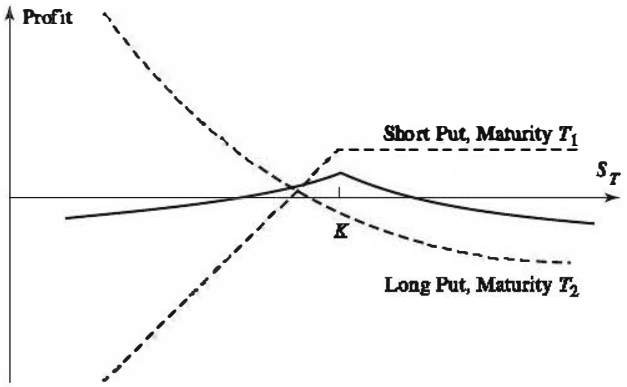

FIGURE 13-9 Profit from calendar spread created using two put options, calculated at the time when the short-maturity put option expires.

To understand the profit pattern from a calendar spread, first consider what happens if the stock price is very low when the short-maturity option expires. The short-maturity option is worthless and the value of the long-maturity option is close to zero. The investor therefore incurs a loss that is close to the cost of setting up the spread initially. Consider next what happens if the stock price, S_T, is very high when the short-maturity option expires. The short-maturity option costs the investor $S_T - K$, and the long-maturity option is worth close to $S_T - K$, where K is the strike price of the options. Again, the investor makes a net loss that is close to the cost of setting up the spread initially. If S_T is close to K, the short-maturity option costs the investor either a small amount or nothing at all. However, the long-maturity option is still quite valuable. In this case a significant net profit is made.

In a *neutral calendar spread*, a strike price close to the current stock price is chosen. A *bullish calendar spread* involves a higher strike price, whereas a *bearish calendar spread* involves a lower strike price.

Calendar spreads can be created with put options as well as call options. The investor buys a long-maturity put option and sells a short-maturity put option. As shown in Figure 13-9, the profit pattern is similar to that obtained from using calls.

A *reverse calendar spread* is the opposite to that in Figures 13-8 and 13-9. The investor buys a short-maturity option and sells a long-maturity option. A small profit arises if the stock price at the expiration of the short-maturity option is well above or well below the strike price of the short-maturity option. However, a loss results if it is close to the strike price.

Diagonal Spreads

Bull, bear, and calendar spreads can all be created from a long position in one call and a short position in another call. In the case of bull and bear spreads, the calls have different strike prices and the same expiration date. In the case of calendar spreads, the calls have the same strike price and different expiration dates.

In a *diagonal spread* both the expiration date and the strike price of the calls are different. This increases the range of profit patterns that are possible.

COMBINATIONS

A *combination* is an option trading strategy that involves taking a position in both calls and puts on the same stock. We will consider straddles, strips, straps, and strangles.

Straddle

One popular combination is a *straddle*, which involves buying a European call and put with the same strike price and expiration date. The profit pattern is shown in Figure 13-10. The strike price is denoted by K. If the stock price is close to this strike price at expiration of the options, the straddle leads to a loss. However, if there is a sufficiently large move in either direction, a significant

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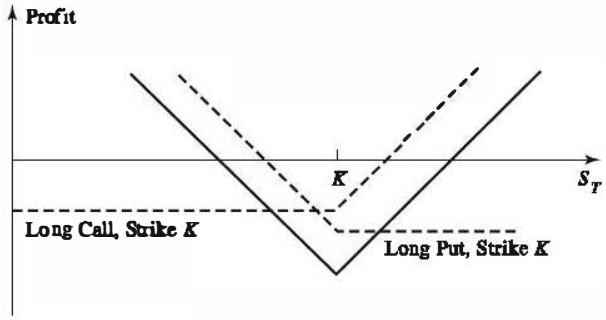

FIGURE 13-10 Profit from a straddle.

profit will result. The payoff from a straddle is calculated in Table 13-5.

A straddle is appropriate when an investor is expecting a large move in a stock price but does not know in which direction the move will be. Consider an investor who feels that the price of a certain stock, currently valued at $69 by the market, will move significantly in the next 3 months. The investor could create a straddle by buying both a put and a call with a strike price of $70 and an expiration date in 3 months. Suppose that the call costs $4 and the put costs $3. If the stock price stays at $69, it is easy to see that the strategy costs the investor $6. (An up-front investment of $7 is required, the call expires worthless, and the put expires worth $1.) If the stock price moves to $70, a loss of $7 is experienced. (This is the worst that can happen.) However, if the stock price jumps up to $90, a profit of $13 is made; if the stock moves down to $55, a profit of $8 is made; and so on. As discussed in Box 13-2 an investor should carefully consider whether the jump that he or she anticipates is already reflected in option prices before putting on a straddle trade.

The straddle in Figure 13-10 is sometimes referred to as a *bottom straddle* or *straddle purchase*. A *top straddle* or *straddle write* is the reverse position. It is created by selling a call and a put with the same exercise price and expiration date. It is a highly risky strategy. If the stock price on the expiration date is close to the strike price, a profit results. However, the loss arising from a large move is unlimited.

TABLE 13-5 Payoff from a Straddle

Range of Stock Price	Payoff from Call	Payoff from Put	Total Payoff
$S_T \le K$	0	$K - S_T$	$K - S_T$
$S_T > K$	$S_T - K$	0	$S_T - K$

BOX 13-2 How to Make Money from Trading Straddles

Suppose that a big move is expected in a company's stock price because there is a takeover bid for the company or the outcome of a major lawsuit involving the company is about to be announced. Should you trade a straddle?

A straddle seems a natural trading strategy in this case. However, if your view of the company's situation is much the same as that of other market participants, this view will be reflected in the prices of options. Options on the stock will be significantly more expensive than options on a similar stock for which no jump is expected. The V-shaped profit pattern from the straddle in Figure 13-10 will have moved downward, so that a bigger move in the stock price is necessary for you to make a profit.

For a straddle to be an effective strategy, you must believe that there are likely to be big movements in the stock price and these beliefs must be different from those of most other investors. Market prices incorporate the beliefs of market participants. To make money from any investment strategy, you must take a view that is different from most of the rest of the market—and you must be right!

Strips and Straps

A *strip* consists of a long position in one European call and two European puts with the same strike price and expiration date. A *strap* consists of a long position in two European calls and one European put with the same strike price and expiration date. The profit patterns from strips and straps are shown in Figure 13-11. In a strip the investor is betting that there will be a big stock price move and considers a decrease in the stock price to be more likely than an increase. In a strap the investor is also betting that there will be a big stock price move. However, in this case, an increase in the stock price is considered to be more likely than a decrease.

Strangles

In a *strangle*, sometimes called a *bottom vertical combination*, an investor buys a European put and a European call

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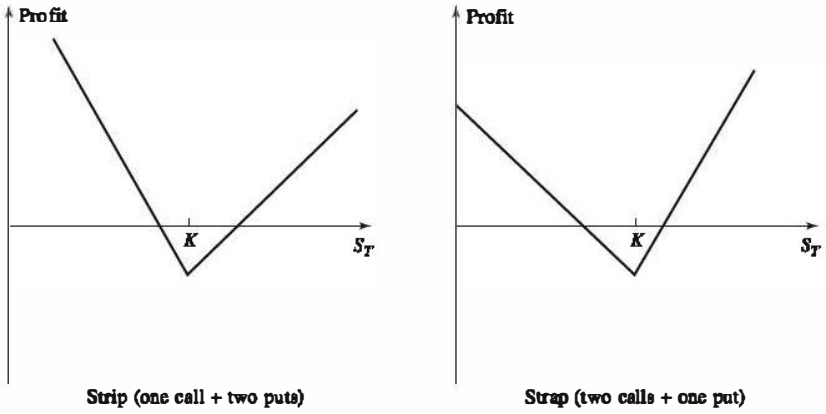

FIGURE 13-11 Profit from a strip and a strap.

with the same expiration date and different strike prices. The profit pattern is shown in Figure 13-12. The call strike price, K_2, is higher than the put strike price, K_1. The payoff function for a strangle is calculated in Table 13-6.

A strangle is a similar strategy to a straddle. The investor is betting that there will be a large price move, but is uncertain whether it will be an increase or a decrease. Comparing Figures 13-12 and 13-10, we see that the stock price has to move farther in a strangle than in a straddle for the investor to make a profit. However, the downside risk if the stock price ends up at a central value is less with a strangle.

The profit pattern obtained with a strangle depends on how close together the strike prices are. The farther they are apart, the less the downside risk and the farther the stock price has to move for a profit to be realized.

The sale of a strangle is sometimes referred to as a *top vertical combination*. It can be appropriate for an investor who feels that large stock price moves are unlikely.

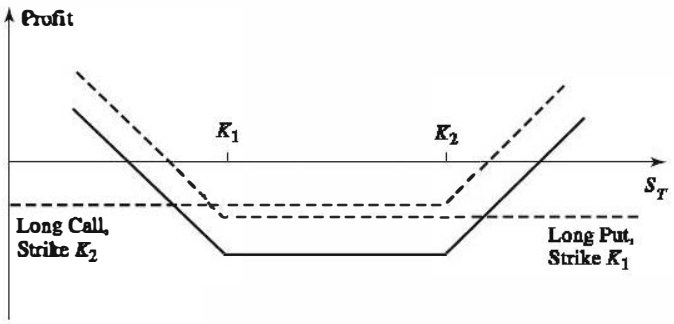

FIGURE 13-12 Profit from a strangle.

TABLE 13-6 Payoff from a Strangle

Range of Stock Price	Payoff from Call	Payoff from Put	Total Payoff
$S_T \le K_1$	0	$K_1 - S_T$	$K_1 - S_T$
$K_1 < S_T < K_2$	0	0	0
$S_T \ge K_2$	$S_T - K_2$	0	$S_T - K_2$

However, as with sale of a straddle, it is a risky strategy involving unlimited potential loss to the investor.

OTHER PAYOFFS

This chapter has demonstrated just a few of the ways in which options can be used to produce an interesting relationship between profit and stock price. If European options expiring at time T were available with every single possible strike price, any payoff function at time T could in theory be obtained. The easiest illustration of this involves butterfly spreads. Recall that a butterfly spread is created by buying options with strike prices K_1 and K_3 and selling two options with strike price K_2, where $K_1 < K_2 < K_3$ and $K_3 - K_2 = K_2 - K_1$. Figure 13-13 shows the payoff from a butterfly spread. The pattern could be described as a spike. As K_1 and K_3 move closer together, the spike becomes smaller. Through the judicious combination of a large number of very small spikes, any payoff function can be approximated as accurately as desired.

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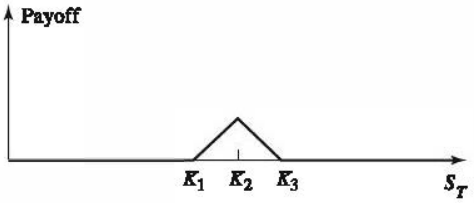

FIGURE 13-13 "Spike payoff" from a butterfly spread that can be used as a building block to create other payoffs.

SUMMARY

Principal-protected notes can be created from a zero-coupon bond and a European call option. They are attractive to some investors because the issuer of the product guarantees that the purchaser will receive his or her principal back regardless of the performance of the asset underlying the option.

A number of common trading strategies involve a single option and the underlying stock. For example, writing a covered call involves buying the stock and selling a call option on the stock; a protective put involves buying a put option and buying the stock. The former is similar to selling a put option; the latter is similar to buying a call option.

Spreads involve either taking a position in two or more calls or taking a position in two or more puts. A bull spread can be created by buying a call (put) with a low strike price and selling a call (put) with a high strike price. A bear spread can be created by buying a put (call) with a high strike price and selling a put (call) with a low strike price. A butterfly spread involves buying calls (puts) with a low and high strike price and selling two calls (puts) with some intermediate strike price. A calendar spread involves selling a call (put) with a short time to expiration and buying a call (put) with a longer time to expiration. A diagonal spread involves a long position in one option and a short position in another option such that both the strike price and the expiration date are different.

Combinations involve taking a position in both calls and puts on the same stock. A straddle combination involves taking a long position in a call and a long position in a put with the same strike price and expiration date. A strip consists of a long position in one call and two puts with the same strike price and expiration date. A strap consists of a long position in two calls and one put with the same strike price and expiration date. A strangle consists of a long position in a call and a put with different strike prices and the same expiration date. There are many other ways in which options can be used to produce interesting payoffs. It is not surprising that option trading has steadily increased in popularity and continues to fascinate investors.

Further Reading

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Exotic Options

14

Learning Objectives

After completing this reading you should be able to:

- Define and contrast exotic derivatives and plain vanilla derivatives.
- Describe some of the factors that drive the development of exotic products.
- Explain how any derivative can be converted into a zero-cost product.
- Describe how standard American options can be transformed into nonstandard American options.
- Identify and describe the characteristics and pay-off structure of the following exotic options: gap, forward start, compound, chooser, barrier, binary, lookback, shout, Asian, exchange, rainbow, and basket options.
- Describe and contrast volatility and variance swaps.
- Explain the basic premise of static option replication and how it can be applied to hedging exotic options.

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Excerpt is Chapter 26 of Options, Futures, and Other Derivatives, *Ninth Edition, by John C. Hull.*

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Derivatives such as European and American call and put options are what are termed *plain vanilla products*. They have standard well-defined properties and trade actively. Their prices or implied volatilities are quoted by exchanges or by interdealer brokers on a regular basis. One of the exciting aspects of the over-the-counter derivatives market is the number of nonstandard products that have been created by financial engineers. These products are termed *exotic options*, or simply *exotics*. Although they usually constitute a relatively small part of its portfolio, these exotics are important to a derivatives dealer because they are generally much more profitable than plain vanilla products.

Exotic products are developed for a number of reasons. Sometimes they meet a genuine hedging need in the market; sometimes there are tax, accounting, legal, or regulatory reasons why corporate treasurers, fund managers, and financial institutions find exotic products attractive; sometimes the products are designed to reflect a view on potential future movements in particular market variables; occasionally an exotic product is designed by a derivatives dealer to appear more attractive than it is to an unwary corporate treasurer or fund manager.

In this chapter, we describe some of the more commonly occurring exotic options and discuss their valuation. We assume that the underlying asset provides a yield at rate q. For an option on a stock index q should be set equal to the dividend yield on the index, for an option on a currency it should be set equal to the foreign risk-free rate, and for an option on a futures contract it should be set equal to the domestic risk-free rate. Many of the options discussed in this chapter can be valued using the DerivaGem software.

PACKAGES

A *package* is a portfolio consisting of standard European calls, standard European puts, forward contracts, cash, and the underlying asset itself. We discussed a number of different types of packages in Chapter 13: bull spreads, bear spreads, butterfly spreads, calendar spreads, straddles, strangles, and so on.

Often a package is structured by traders so that it has zero cost initially. An example is *a range forward contract*.[1] It consists of a long call and a short put or a short call and a long put. The call strike price is greater than the put strike price and the strike prices are chosen so that the value of the call equals the value of the put.

It is worth noting that any derivative can be converted into a zero-cost product by deferring payment until maturity. Consider a European call option. If c is the cost of the option when payment is made at time zero, then $A = ce^{rT}$ is the cost when payment is made at time T, the maturity of the option. The payoff is then $\max(S_T - K, 0) - A$ or $\max(S_T - K - A, -A)$. When the strike price, K, equals the forward price, other names for a deferred payment option are break forward, Boston option, forward with optional exit, and cancelable forward.

PERPETUAL AMERICAN CALL AND PUT OPTIONS

The differential equation that must be satisfied by the price of a derivative when there is a dividend at rate q is:

$$\frac{\partial f}{\partial t} + (r - q)S\frac{\partial f}{\partial S} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 f}{\partial S^2} = rf$$

Consider a derivative that pays off a fixed amount Q when $S = H$ for the first time. If $S < H$, the boundary conditions for the differential equation are that $f = Q$ when $S = H$ and $f = 0$ when $S = 0$. The solution $f = Q(S/H)^\alpha$ satisfies the boundary conditions when $\alpha > 0$. Furthermore, it satisfies the differential equation when

$$(r - q)\alpha + \frac{1}{2}\alpha(\alpha - 1)\sigma^2 = r$$

The positive solution to this equation is $\alpha = \alpha_1$, where

$$\alpha_1 = \frac{-w + \sqrt{w^2 + 2\sigma^2 r}}{\sigma^2}$$

and $w = r - q - \sigma^2/2$. It follows that the value of the derivative must be $Q(S/H)^{\alpha_1}$ because this satisfies the boundary conditions and the differential equation.

Consider next a perpetual American call option with strike price K. If the option is exercised when $S = H$, the payoff is $H - K$ and from the result just proved the value of the option is $(H - K)(S/H)^{\alpha_1}$. The holder of the call option can choose the asset price, H, at which the option is exercised. The optimal H is the one that maximizes the value we have just calculated. Using standard calculus methods, it is $H = H_1$, where

[1] Other names used for a range forward contract are zero-cost collar, flexible forward, cylinder option, option fence, min-max, and forward band.

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$$H_1 = K\frac{\alpha_1}{\alpha_1 - 1}$$

The price of a perpetual call if $S < H_1$ is therefore

$$\frac{K}{\alpha_1 - 1}\left(\frac{\alpha_1 - 1}{\alpha_1}\frac{S}{K}\right)^{\alpha_1}$$

If $S > H_1$, the call should be exercised immediately and is worth $S - K$.

To value an American put, we consider a derivative that pays off Q when $S = H$ in the situation where $S > H$ (so that the barrier H is reached from above). In this case, the boundary conditions for the differential equation are that $f = Q$ when $S = H$ and $f = 0$ as S tends to infinity. In this case, the solution $f = Q(S/H)^{-\alpha}$ satisfies the boundary conditions when $\alpha > 0$. As above, we can show that it also satisfies the differential equation when $\alpha = \alpha_2$, where

$$\alpha_2 = \frac{w + \sqrt{w^2 + 2\sigma^2 r}}{\sigma^2}$$

If the holder of the American put chooses to exercise when $S = H$, the value of the put is $(K - H)(S/H)^{-\alpha_2}$. The holder of the put will choose the exercise level $H = H_2$ to maximize this. This is

$$H_2 = K\frac{\alpha_2}{\alpha_2 + 1}$$

The price of a perpetual put if $S > H_2$ is therefore

$$\frac{K}{\alpha_2 + 1}\left(\frac{\alpha_2 + 1}{\alpha_2}\frac{S}{K}\right)^{-\alpha_2}$$

If $S < H_2$, the put should be exercised immediately and is worth $K - S$.

NONSTANDARD AMERICAN OPTIONS

In a standard American option, exercise can take place at any time during the life of the option and the exercise price is always the same. The American options that are traded in the over-the-counter market sometimes have nonstandard features. For example:

1. Early exercise may be restricted to certain dates. The instrument is then known as a *Bermudan option*. (Bermuda is between Europe and America!)
2. Early exercise may be allowed during only part of the life of the option. For example, there may be an initial "lock out" period with no early exercise.
3. The strike price may change during the life of the option.

The warrants issued by corporations on their own stock often have some or all of these features. For example, in a 7-year warrant, exercise might be possible on particular dates during years 3 to 7, with the strike price being \$30 during years 3 and 4, \$32 during the next 2 years, and \$33 during the final year.

Nonstandard American options can usually be valued using a binomial tree. At each node, the test (if any) for early exercise is adjusted to reflect the terms of the option.

GAP OPTIONS

A gap call option is a European call options that pays off $S_T - K_1$ when $S_T > K_2$. The difference between a gap call option and a regular call option with a strike price of K_2 is that the payoff when $S_T > K_2$ is increased by $K_2 - K_1$. (This increase is positive or negative depending on whether $K_2 > K_1$ or $K_1 > K_2$.)

A gap call option can be valued by a small modification to the Black–Scholes–Merton formula. With our usual notation, the value is

$$S_0 e^{-qT} N(d_1) - K_1 e^{-rT} N(d_2) \qquad (14.1)$$

where

$$d_1 = \frac{\ln(S_0/K_2) + (r - q + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

The price in this formula is greater than the price given by the Black–Scholes–Merton formula for a regular call option with strike price K_2 by

$$(K_2 - K_1)e^{-rT} N(d_2)$$

To understand this difference, note that the probability that the option will be exercised is $N(d_2)$ and, when it is exercised, the payoff to the holder of the gap option is greater than that to the holder of the regular option by $K_2 - K_1$.

For a gap put option, the payoff is $K_1 - S_T$ when $S_T < K_2$. The value of the option is

$$K_1 e^{-rT} N(-d_2) - S_0 e^{-qT} N(-d_1) \qquad (14.2)$$

where d_1 and d_2 are defined as for Equation (14.1).

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Example 14.1

An asset is currently worth $500,000. Over the next year, it is expected to have a volatility of 20%. The risk-free rate is 5%, and no income is expected. Suppose that an insurance company agrees to buy the asset for $400,000 if its value has fallen below $400,000 at the end of one year. The payout will be $400,000 - S_T$ whenever the value of the asset is less than $400,000. The insurance company has provided a regular put option where the policyholder has the right to sell the asset to the insurance company for $400,000 in one year. This can be valued with $S_0 = 500{,}000$, $K = 400{,}000$, $r = 0.05$, $\sigma = 0.2$, $T = 1$. The value is $3,436.

Suppose next that the cost of transferring the asset is $50,000 and this cost is borne by the policyholder. The option is then exercised only if the value of the asset is less than $350,000. In this case, the cost to the insurance company is $K_1 - S_T$ when $S_T < K_2$, where $K_2 = 350{,}000$, $K_1 = 400{,}000$, and S_T is the price of the asset in one year. This is a gap put option. The value is given by Equation (14.2), with $S_0 = 500{,}000$, $K_1 = 400{,}000$, $K_2 = 350{,}000$, $r = 0.05$, $q = 0$, $\sigma = 0.2$, $T = 1$. It is $1,896. Recognizing the costs to the policyholder of making a claim reduces the cost of the policy to the insurance company by about 45% in this case.

FORWARD START OPTIONS

Forward start options are options that will start at some time in the future. Sometimes employee stock options can be viewed as forward start options. This is because the company commits (implicitly or explicitly) to granting at-the-money options to employees in the future.

Consider a forward start at-the-money European call option that will start at time T_1 and mature at time T_2. Suppose that the asset price is S_0 at time zero and S_1 at time T_1. To value the option, we note from the European option pricing formulas that the value of an at-the-money call option on an asset is proportional to the asset price. The value of the forward start option at time T_1 is therefore cS_1/S_0, where c is the value at time zero of an at-the-money option that lasts for $T_2 - T_1$. Using risk-neutral valuation, the value of the forward start option at time zero is

$$e^{-rT_1}\hat{E}\left[c\frac{S_1}{S_0}\right]$$

where $\hat{E}$ denotes the expected value in a risk-neutral world. Since c and S_0 are known and $\hat{E}[S_1] = S_0 e^{(r-q)T_1}$, the value of the forward start option is ce^{-qT_1}. For a non-dividend-paying stock, $q = 0$ and the value of the forward start option is exactly the same as the value of a regular at-the-money option with the same life as the forward start option.

CLIQUET OPTIONS

A cliquet option (which is also called a ratchet or strike reset option) is a series of call or put options with rules for determining the strike price. Suppose that the reset dates are at times $\tau, 2\tau, \ldots, (n-1)\tau$, with $n\tau$ being the end of the cliquet's life. A simple structure would be as follows. The first option has a strike price K (which might equal the initial asset price) and lasts between times 0 and τ; the second option provides a payoff at time 2τ with a strike price equal to the value of the asset at time τ; the third option provides a payoff at time 3τ with a strike price equal to the value of the asset at time 2τ; and so on. This is a regular option plus $n - 1$ forward start options. The latter can be valued as described in the previous section.

Some cliquet options are much more complicated than the one described here. For example, sometimes there are upper and lower limits on the total payoff over the whole period; sometimes cliquets terminate at the end of a period if the asset price is in a certain range. When analytic results are not available, Monte Carlo simulation is often the best approach for valuation.

COMPOUND OPTIONS

Compound options are options on options. There are four main types of compound options: a call on a call, a put on a call, a call on a put, and a put on a put. Compound options have two strike prices and two exercise dates. Consider, for example, a call on a call. On the first exercise date, T_1, the holder of the compound option is entitled to pay the first strike price, K_1, and receive a call option. The call option gives the holder the right to buy the underlying asset for the second strike price, K_2, on the second exercise date, T_2. The compound option will be exercised on the first exercise date only if the value of the option on that date is greater than the first strike price.

When the usual geometric Brownian motion assumption is made, European-style compound options can be valued

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analytically in terms of integrals of the bivariate normal distribution.[2] With our usual notation, the value at time zero of a European call option on a call option is

$$S_0e^{-qT_2}M\left(a_1, b_1; \sqrt{T_1/T_2}\right) - K_2e^{-rT_2}M\left(a_2, b_2; \sqrt{T_1/T_2}\right) - e^{-rT_1}K_1N(a_2)$$

where

$$a_1 = \frac{\ln(S_0/S^*) + (r - q + \sigma^2/2)T_1}{\sigma\sqrt{T_1}}, \qquad a_2 = a_1 - \sigma\sqrt{T_1}$$

$$b_1 = \frac{\ln(S_0/K_2) + (r - q + \sigma^2/2)T_2}{\sigma\sqrt{T_2}}, \qquad b_2 = b_1 - \sigma\sqrt{T_2}$$

The function $M(a, b : \rho)$ is the cumulative bivariate normal distribution function that the first variable will be less than a and the second will be less than b when the coefficient of correlation between the two is ρ.[3] The variable S^* is the asset price at time T_1 for which the option price at time T_1 equals K_1. If the actual asset price is above S^* at time T_1 the first option will be exercised; if it is not above S^*, the option expires worthless.

With similar notation, the value of a European put on a call is

$$K_2e^{-rT_2}M\left(-a_2, b_2; -\sqrt{T_1/T_2}\right) - S_0e^{-qT_2}M\left(-a_1, b_1; -\sqrt{T_1/T_2}\right) + e^{-rT_1}K_1N(-a_2)$$

The value of a European call on a put is

$$K_2e^{-rT_2}M\left(-a_2, -b_2; \sqrt{T_1/T_2}\right) - S_0e^{-qT_2}M\left(-a_1, -b_1; \sqrt{T_1/T_2}\right) - e^{-rT_1}K_1N(-a_2)$$

The value of a European put on a put is

$$S_0e^{-qT_2}M\left(a_1, -b_1; -\sqrt{T_1/T_2}\right) - K_2e^{-rT_2}M\left(a_2, -b_2; -\sqrt{T_1/T_2}\right) + e^{-rT_1}K_1N(a_2)$$

CHOOSER OPTIONS

A *chooser* option (sometimes referred to as an *as you like it* option) has the feature that, after a specified period of time, the holder can choose whether the option is a call or a put. Suppose that the time when the choice is made is T_1. The value of the chooser option at this time is

$$\max(c, p)$$

where c is the value of the call underlying the option and p is the value of the put underlying the option.

If the options underlying the chooser option are both European and have the same strike price, put–call parity can be used to provide a valuation formula. Suppose that S_1 is the asset price at time T_1, K is the strike price, T_2 is the maturity of the options, and r is the risk-free interest rate. Put–call parity implies that

$$\max(c, p) = \max(c, c + Ke^{-r(T_2-T_1)} - S_1e^{-q(T_2-T_1)})$$
$$= c + e^{-q(T_2-T_1)}\max(0, Ke^{-(r-q)(T_2-T_1)} - S_1)$$

This shows that the chooser option is a package consisting of:

1. A call option with strike price K and maturity T_2
2. $e^{-q(T_2-T_1)}$ put options with strike price $Ke^{-(r-q)(T_2-T_1)}$ and maturity T_1

As such, it can readily be valued.

More complex chooser options can be defined where the call and the put do not have the same strike price and time to maturity. They are then not packages and have features that are somewhat similar to compound options.

BARRIER OPTIONS

Barrier options are options where the payoff depends on whether the underlying asset's price reaches a certain level during a certain period of time.

A number of different types of barrier options regularly trade in the over-the-counter market. They are attractive to some market participants because they are less expensive than the corresponding regular options. These barrier options can be classified as either *knock-out options* or *knock-in options*. A knock-out option ceases to exist when the underlying asset price reaches a certain barrier; a knock-in option comes into existence only when the underlying asset price reaches a barrier.

The values at time zero of a regular call and put option are

$$c = S_0e^{-qT}N(d_1) - Ke^{-rT}N(d_2)$$
$$p = Ke^{-rT}N(-d_2) - S_0e^{-qT}N(-d_1)$$

[2] See R. Geske, "The Valuation of Compound Options," *Journal of Financial Economics*, 7 (1979): 63–81; M. Rubinstein, "Double Trouble," *Risk*, December 1991/January 1992: 53–56.

[3] See Technical Note 5 at www.rotman.utoronto.ca/~hull/TechnicalNotes for a numerical procedure for calculating M. A function for calculating M is also on the website.

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where

$$d_1 = \frac{\ln(S_0/K) + (r - q + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln(S_0/K) + (r - q + \sigma^2/2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

A *down-and-out call* is one type of knock-out option. It is a regular call option that ceases to exist if the asset price reaches a certain barrier level H. The barrier level is below the initial asset price. The corresponding knock-in option is a *down-and-in call*. This is a regular call that comes into existence only if the asset price reaches the barrier level.

If H is less than or equal to the strike price, K, the value of a down-and-in call at time zero is

$$c_{di} = S_0 e^{-qT}(H/S_0)^{2\lambda} N(y) - Ke^{-rT}(H/S_0)^{2\lambda-2} N\left(y - \sigma\sqrt{T}\right)$$

where

$$\lambda = \frac{r - q + \sigma^2/2}{\sigma^2}$$

$$y = \frac{\ln[H^2/(S_0 K)]}{\sigma\sqrt{T}} + \lambda\sigma\sqrt{T}$$

Because the value of a regular call equals the value of a down-and-in call plus the value of a down-and-out call, the value of a down-and-out call is given by

$$c_{do} = c - c_{di}$$

If $H \geq K$, then

$$c_{do} = S_0 N(x_1)e^{-qT} - Ke^{-rT} N\left(x_1 - \sigma\sqrt{T}\right) - S_0 e^{-qT}(H/S_0)^{2\lambda} N(y_1) + Ke^{-rT}(H/S_0)^{2\lambda-2} N\left(y_1 - \sigma\sqrt{T}\right)$$

and

$$c_{di} = c - c_{do}$$

where

$$x_1 = \frac{\ln(S_0/H)}{\sigma\sqrt{T}} + \lambda\sigma\sqrt{T}, \qquad y_1 = \frac{\ln(H/S_0)}{\sigma\sqrt{T}} + \lambda\sigma\sqrt{T}$$

An *up-and-out call* is a regular call option that ceases to exist if the asset price reaches a barrier level, H, that is higher than the current asset price. An *up-and-in call* is a regular call option that comes into existence only if the barrier is reached. When H is less than or equal to K, the value of the up-and-out call, c_{uo}, is zero and the value of the up-and-in call, c_{ui}, is c. When H is greater than K,

$$c_{ui} = S_0 N(x_1)e^{-qT} - Ke^{-rT} N\left(x_1 - \sigma\sqrt{T}\right) - S_0 e^{-qT}(H/S_0)^{2\lambda}[N(-y) - N(-y_1)] + Ke^{-rT}(H/S_0)^{2\lambda-2}\left[N\left(-y + \sigma\sqrt{T}\right) - N\left(-y_1 + \sigma\sqrt{T}\right)\right]$$

and

$$c_{uo} = c - c_{ui}$$

Put barrier options are defined similarly to call barrier options. An *up-and-out put* is a put option that ceases to exist when a barrier, H, that is greater than the current asset price is reached. An *up-and-in put* is a put that comes into existence only if the barrier is reached. When the barrier, H, is greater than or equal to the strike price, K, their prices are

$$p_{ui} = -S_0 e^{-qT}(H/S_0)^{2\lambda} N(-y) + Ke^{-rT}(H/S_0)^{2\lambda-2} N\left(-y + \sigma\sqrt{T}\right)$$

and

$$p_{uo} = p - p_{ui}$$

When H is less than or equal to K,

$$p_{uo} = -S_0 N(-x_1)e^{-qT} + Ke^{-rT} N\left(-x_1 + \sigma\sqrt{T}\right) + S_0 e^{-qT}(H/S_0)^{2\lambda} N(-y_1) - Ke^{-rT}(H/S_0)^{2\lambda-2} N\left(-y_1 + \sigma\sqrt{T}\right)$$

and

$$p_{ui} = p - p_{uo}$$

A *down-and-out put* is a put option that ceases to exist when a barrier less than the current asset price is reached. A *down-and-in put* is a put option that comes into existence only when the barrier is reached. When the barrier is greater than the strike price, $p_{do} = 0$ and $p_{di} = p$. When the barrier is less than the strike price,

$$p_{di} = -S_0 N(-x_1)e^{-qT} + Ke^{-rT} N\left(-x_1 + \sigma\sqrt{T}\right) + S_0 e^{-qT}(H/S_0)^{2\lambda}[N(y) - N(y_1)] - Ke^{-rT}(H/S_0)^{2\lambda-2}\left[N\left(y - \sigma\sqrt{T}\right) - N\left(y_1 - \sigma\sqrt{T}\right)\right]$$

and

$$p_{do} = p - p_{di}$$

All of these valuations make the usual assumption that the probability distribution for the asset price at a future time is lognormal. An important issue for barrier options is the frequency with which the asset price, S, is observed for purposes of determining whether the barrier has been reached. The analytic formulas given in

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this section assume that S is observed continuously and sometimes this is the case.[4] Often, the terms of a contract state that S is observed periodically; for example, once a day at 3 p.m. Broadie, Glasserman, and Kou provide a way of adjusting the formulas we have just given for the situation where the price of the underlying is observed discretely.[5] The barrier level H is replaced by $He^{0.5826\sigma\sqrt{T/m}}$ for an up-and-in or up-and-out option and by $He^{-0.5826\sigma\sqrt{T/m}}$ for a down-and-in or down-and-out option, where m is the number of times the asset price is observed (so that T/m is the time interval between observations).

Barrier options often have quite different properties from regular options. For example, sometimes vega is negative. Consider an up-and-out call option when the asset price is close to the barrier level. As volatility increases, the probability that the barrier will be hit increases. As a result, a volatility increase can cause the price of the barrier option to decrease in these circumstances.

One disadvantage of the barrier options we have considered so far is that a "spike" in the asset price can cause the option to be knocked in or out. An alternative structure is a *Parisian option*, where the asset price has to be above or below the barrier for a period of time for the option to be knocked in or out. For example, a down-and-out Parisian put option with a strike price equal to 90% of the initial asset price and a barrier at 75% of the initial asset price might specify that the option is knocked out if the asset price is below the barrier for 50 days. The confirmation might specify that the 50 days are a "continuous period of 50 days" or "any 50 days during the option's life." Parisian options are more difficult to value than regular barrier options.[6] Monte Carlo simulation and binomial trees can be used with the enhancements discussed in previous sections.

[4] One way to track whether a barrier has been reached from below (above) is to send a limit order to the exchange to sell (buy) the asset at the barrier price and see whether the order is filled.

[5] M. Broadie, P. Glasserman, and S. G. Kou, "A Continuity Correction for Discrete Barrier Options," *Mathematical Finance* 7, 4 (October 1997): 325–49.

[6] See, for example, M. Chesney, J. Cornwall, M. Jeanblanc-Picqué, G. Kentwell, and M. Yor, "Parisian pricing," *Risk*, 10, 1 (1997), 77–79.

BINARY OPTIONS

Binary options are options with discontinuous payoffs. A simple example of a binary option is a *cash-or-nothing call*. This pays off nothing if the asset price ends up below the strike price at time T and pays a fixed amount, Q, if it ends up above the strike price. In a risk-neutral world, the probability of the asset price being above the strike price at the maturity of an option is, with our usual notation, $N(d_2)$. The value of a cash-or-nothing call is therefore $Qe^{-rT}N(d_2)$. A *cash-or-nothing put* is defined analogously to a cash-or-nothing call. It pays off Q if the asset price is below the strike price and nothing if it is above the strike price. The value of a cash-or-nothing put is $Qe^{-rT}N(-d_2)$.

Another type of binary option is an *asset-or-nothing call*. This pays off nothing if the underlying asset price ends up below the strike price and pays the asset price if it ends up above the strike price. With our usual notation, the value of an asset-or-nothing call is $S_0e^{-qT}N(d_1)$. An *asset-or-nothing put* pays off nothing if the underlying asset price ends up above the strike price and the asset price if it ends up below the strike price. The value of an asset-or-nothing put is $S_0e^{-qT}N(-d_1)$.

A regular European call option is equivalent to a long position in an asset-or-nothing call and a short position in a cash-or-nothing call where the cash payoff in the cash-or-nothing call equals the strike price. Similarly, a regular European put option is equivalent to a long position in a cash-or-nothing put and a short position in an asset-or-nothing put where the cash payoff on the cash-or-nothing put equals the strike price.

LOOKBACK OPTIONS

The payoffs from lookback options depend on the maximum or minimum asset price reached during the life of the option. The payoff from a *floating lookback call* is the amount that the final asset price exceeds the minimum asset price achieved during the life of the option. The payoff from a *floating lookback put* is the amount by which the maximum asset price achieved during the life of the option exceeds the final asset price.

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Valuation formulas have been produced for floating lookbacks.[7] The value of a floating lookback call at time zero is

$$c_{fl} = S_0 e^{-qT} N(a_1) - S_0 e^{-qT} \frac{\sigma^2}{2(r-q)} N(-a_1)$$
$$- S_{min} e^{-rT} \left[N(a_2) - \frac{\sigma^2}{2(r-q)} e^{Y_1} N(-a_3) \right]$$

where

$$a_1 = \frac{\ln(S_0/S_{min}) + (r - q + \sigma^2/2)T}{\sigma\sqrt{T}}$$
$$a_2 = a_1 - \sigma\sqrt{T},$$
$$a_3 = \frac{\ln(S_0/S_{min}) + (-r + q + \sigma^2/2)T}{\sigma\sqrt{T}}$$
$$Y_1 = -\frac{2(r - q - \sigma^2/2)\ln(S_0/S_{min})}{\sigma^2}$$

and S_{min} is the minimum asset price achieved to date. (If the lookback has just been originated, $S_{min} = S_0$.)

The value of a floating lookback put is

$$p_{fl} = S_{max} e^{-rT} \left[N(b_1) - \frac{\sigma^2}{2(r-q)} e^{Y_2} N(-b_3) \right]$$
$$+ S_0 e^{-qT} \frac{\sigma^2}{2(r-q)} N(-b_2) - S_0 e^{-qT} N(b_2)$$

where

$$b_1 = \frac{\ln(S_{max}/S_0) + (-r + q + \sigma^2/2)T}{\sigma\sqrt{T}}$$
$$b_2 = b_1 - \sigma\sqrt{T}$$
$$b_3 = \frac{\ln(S_{max}/S_0) + (r - q - \sigma^2/2)T}{\sigma\sqrt{T}}$$
$$Y_2 = \frac{2(r - q - \sigma^2/2)\ln(S_{max}/S_0)}{\sigma^2}$$

and S_{max} is the maximum asset price achieved to date. (If the lookback has just been originated, then $S_{max} = S_0$.)

A floating lookback call is a way that the holder can buy the underlying asset at the lowest price achieved during the life of the option. Similarly, a floating lookback put is a way that the holder can sell the underlying asset at the highest price achieved during the life of the option.

Example 14.2

Consider a newly issued floating lookback put on a non-dividend-paying stock where the stock price is 50, the stock price volatility is 40% per annum, the risk-free rate is 10% per annum, and the time to maturity is 3 months. In this case, $S_{max} = 50$, $S_0 = 50$, $r = 0.1$, $q = 0$, $\sigma = 0.4$, and $T = 0.25$, $b_1 = -0.025$, $b_2 = -0.225$, $b_3 = 0.025$, and $Y_2 = 0$, so that the value of the lookback put is 7.79. A newly issued floating lookback call on the same stock is worth 8.04.

In a fixed lookback option, a strike price is specified. For a *fixed lookback call option*, the payoff is the same as a regular European call option except that the final asset price is replaced by the maximum asset price achieved during the life of the option. For a *fixed lookback put option*, the payoff is the same as a regular European put option except that the final asset price is replaced by the minimum asset price achieved during the life of the option. Define $S^*_{max} = \max(S_{max}, K)$, where as before S_{max} is the maximum asset price achieved to date and K is the strike price. Also, define p^*_{fl} as the value of a floating lookback put which lasts for the same period as the fixed lookback call when the actual maximum asset price so far, S_{max}, is replaced by S^*_{max}. A put–call parity type of argument shows that the value of the fixed lookback call option, c_{fix} is given by[8]

$$c_{fix} = p^*_{fl} + S_0 e^{-qT} - Ke^{-rT}$$

Similarly, if $S^*_{min} = \min(S_{min}, K)$, then the value of a fixed lookback put option, p_{fix}, is given by

$$p_{fix} = c^*_{fl} + Ke^{-rT} - S_0 e^{-qT}$$

Where c^*_{fl} is the value of a floating lookback call that lasts for the same period as the fixed lookback put when the actual minimum asset price so far, S_{min}, is replaced by S^*_{min}. This shows that the equations given above for floating lookbacks can be modified to price fixed lookbacks.

Lookbacks are appealing to investors, but very expensive when compared with regular options. As with barrier options, the value of a lookback option is liable to be sensitive to the frequency with which the asset price is observed for the purposes of computing the maximum or minimum. The formulas above assume that the asset price

[7] See B. Goldman, H. Sosin, and M. A. Gatto, "Path-Dependent Options: Buy at the Low, Sell at the High," *Journal of Finance*, 34 (December 1979): 1111–27; M. Garman, "Recollection in Tranquility," *Risk*, March (1989): 16–19.

[8] The argument was proposed by H. Y. Wong and Y. K. Kwok, "Sub-replication and Replenishing Premium: Efficient Pricing of Multi-state Lookbacks," *Review of Derivatives Research*, 6 (2003), 83–106.

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is observed continuously. Broadie, Glasserman, and Kou provide a way of adjusting the formulas we have just given for the situation where the asset price is observed discretely.[9]

SHOUT OPTIONS

A *shout option* is a European option where the holder can "shout" to the writer at one time during its life. At the end of the life of the option, the option holder receives either the usual payoff from a European option or the intrinsic value at the time of the shout, whichever is greater. Suppose the strike price is $50 and the holder of a call shouts when the price of the underlying asset is $60. If the final asset price is less than $60, the holder receives a payoff of $10. If it is greater than $60, the holder receives the excess of the asset price over $50.

A shout option has some of the same features as a lookback option, but is considerably less expensive. It can be valued by noting that if the holder shouts at a time τ when the asset price is S_τ the payoff from the option is

$$\max(0, S_T - S_\tau) + (S_\tau - K)$$

where, as usual, K is the strike price and S_T is the asset price at time T. The value at time τ if the holder shouts is therefore the present value of $S_\tau - K$ (received at time T) plus the value of a European option with strike price S_τ. The latter can be calculated using Black-Scholes-Merton formulas.

A shout option is valued by constructing a binomial or trinomial tree for the underlying asset in the usual way. Working back through the tree, the value of the option if the holder shouts and the value if the holder does not shout can be calculated at each node. The option's price at the node is the greater of the two. The procedure for valuing a shout option is therefore similar to the procedure for valuing a regular American option.

ASIAN OPTIONS

Asian options are options where the payoff depends on the arithmetic average of the price of the underlying asset during the life of the option. The payoff from an *average price call* is $\max(0, S_{ave} - K)$ and that from an *average price put* is $\max(0, K - S_{ave})$, where S_{ave} is the average price of the underlying asset. Average price options are less expensive than regular options and are arguably more appropriate than regular options for meeting some of the needs of corporate treasurers. Suppose that a US corporate treasurer expects to receive a cash flow of 100 million Australian dollars spread evenly over the next year from the company's Australian subsidiary. The treasurer is likely to be interested in an option that guarantees that the average exchange rate realized during the year is above some level. An average price put option can achieve this more effectively than regular put options.

Average price options can be valued using similar formulas to those used for regular options if it is assumed that S_{ave} is lognomal. As it happens, when the usual assumption is made for the process followed by the asset price, this is a reasonable assumption.[10] A popular approach is to fit a lognormal distribution to the first two moments of S_{ave} and use Black's model.[11] Suppose that M_1 and M_2 are the first two moments of S_{ave}. The value of the average price calls and puts are given by:

$$c = e^{-rT}[F_0N(d_1) - KN(d_2)] \quad (14.3)$$

$$p = e^{-rT}[KN(-d_2) - F_0N(-d_1)] \quad (14.4)$$

where

$$d_1 = \frac{\ln(F_0/K) + \sigma^2T/2}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

$$F_0 = M_1$$

$$\sigma^2 = \frac{1}{T}\ln\left(\frac{M_2}{M_1^2}\right)$$

When the average is calculated continuously, and r, q, and σ are constant (as in DerivaGem):

$$M_1 = \frac{e^{(r-q)T} - 1}{(r-q)T}S_0$$

and

$$M_2 = \frac{2e^{[2(r-q)+\sigma^2]T}S_0^2}{(r-q+\sigma^2)(2r-2q+\sigma^2)T^2} + \frac{2S_0^2}{(r-q)T^2}\left(\frac{1}{2(r-q)+\sigma^2} - \frac{e^{(r-q)T}}{r-q+\sigma^2}\right)$$

[9] M. Broadie, P. Glasserman, and S. G. Kou, "Connecting Discrete and Continuous Path-Dependent Options," *Finance and Stochastics*, 2 (1998): 1–28.

[10] When the asset price follows geometric Brownian motion, the geometric average of the price is exactly lognormal and the arithmetic average is approximately lognormal.

[11] See S. M. Turnbull and L. M. Wakeman, "A Quick Algorithm for Pricing European Average Options," *Journal of Financial and Quantitative Analysis*, 26 (September 1991): 377–89.

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More generally, when the average is calculated from observations at times T_i ($1 \le i \le m$),

$$M_1 = \frac{1}{m}\sum_{i=1}^{m} F_i \quad \text{and} \quad M_2 = \frac{1}{m^2}\left(\sum_{i=1}^{m} F_i^2 e^{\sigma_i^2 T_i} + 2\sum_{j=1}^{m}\sum_{i=1}^{j-1} F_i F_j e^{\sigma_i^2 T_i}\right)$$

where F_i and σ_i are the forward price and implied volatility for maturity T_i. See Technical Note 27 on www.rotman.utoronto.ca/~hull/TechnicalNotes for a proof of this.

Example 14.3

Consider a newly issued average price call option on a non-dividend-paying stock where the stock price is 50, the strike price is 50, the stock price volatility is 40% per annum, the risk-free rate is 10% per annum, and the time to maturity is 1 year. In this case, $S_0 = 50$, $K = 50$, $r = 0.1$, $q = 0$, $\sigma = 0.4$, and $T = 1$. If the average is calculated continuously, $M_1 = 52.59$ and $M_2 = 2{,}922.76$. Equation (14.3) with $F_0 = 52.59$, $\sigma = 23.54\%$, $K = 50$, $T = 1$ and $r = 0.1$, gives the value of the option as 5.62. When 12, 52, and 250 observations are used for the average, the price is 6.00, 5.70, and 5.63, respectively.

We can modify the analysis to accommodate the situation where the option is not newly issued and some prices used to determine the average have already been observed. Suppose that the averaging period is composed of a period of length t_1 over which prices have already been observed and a future period of length t_2 (the remaining life of the option). Suppose that the average asset price during the first time period is $\bar{S}$. The payoff from an average price call is

$$\max\left(\frac{\bar{S}t_1 + S_{ave}t_2}{t_1 + t_2} - K, 0\right)$$

where S_{ave} is the average asset price during the remaining part of the averaging period. This is the same as

$$\frac{t_2}{t_1 + t_2}\max(S_{ave} - K^*, 0)$$

where

$$K^* = \frac{t_1 + t_2}{t_2}K - \frac{t_1}{t_2}\bar{S}$$

When $K^* > 0$, the option can be valued in the same way as a newly issued Asian option provided that we change the strike price from K to K^* and multiply the result by $t_2/(t_1 + t_2)$. When $K^* < 0$ the option is certain to be exercised and can be valued as a forward contract. The value is

$$\frac{t_2}{t_1 + t_2}[M_1 e^{-rt_2} - K^* e^{-rt_2}]$$

Another type of Asian option is an average strike option. An *average strike call* pays off $\max(0, S_T - S_{ave})$ and an *average strike put* pays off $\max(0, S_{ave} - S_T)$. Average strike options can guarantee that the average price paid for an asset in frequent trading over a period of time is not greater than the final price. Alternatively, it can guarantee that the average price received for an asset in frequent trading over a period of time is not less than the final price. It can be valued as an option to exchange one asset for another when S_{ave} is assumed to be lognormal.

OPTIONS TO EXCHANGE ONE ASSET FOR ANOTHER

Options to exchange one asset for another (sometimes referred to as *exchange options*) arise in various contexts. An option to buy yen with Australian dollars is, from the point of view of a US investor, an option to exchange one foreign currency asset for another foreign currency asset. A stock tender offer is an option to exchange shares in one stock for shares in another stock.

Consider a European option to give up an asset worth U_T at time T and receive in return an asset worth V_T. The payoff from the option is

$$\max(V_T - U_T, 0)$$

A formula for valuing this option was first produced by Margrabe.[12] Suppose that the asset prices, U and V, both follow geometric Brownian motion with volatilities σ_U and σ_V. Suppose further that the instantaneous correlation between U and V is ρ, and the yields provided by U and V are q_U and q_V, respectively. The value of the option at time zero is

$$V_0 e^{-q_V T} N(d_1) - U_0 e^{-q_U T} N(d_2) \tag{14.5}$$

where

$$d_1 = \frac{\ln(V_0/U_0) + (q_U - q_V + \hat{\sigma}^2/2)T}{\hat{\sigma}\sqrt{T}}, \quad d_2 = d_1 - \hat{\sigma}\sqrt{T}$$

and

$$\hat{\sigma} = \sqrt{\sigma_U^2 + \sigma_V^2 - 2\rho\sigma_U\sigma_V}$$

and U_0 and V_0 are the values of U and V at times zero.

[12] See W. Margrabe, "The Value of an Option to Exchange One Asset for Another," *Journal of Finance*, 33 (March 1978): 177–86.

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It is interesting to note that Equation (14.5) is independent of the risk-free rate r. This is because, as r increases, the growth rate of both asset prices in a risk-neutral world increases, but this is exactly offset by an increase in the discount rate. The variable $\hat{\sigma}$ is the volatility of V/U. The option price is the same as the price of U_0 European call options on an asset worth V/U when the strike price is 1.0, the risk-free interest rate is q_U, and the dividend yield on the asset is q_V. Mark Rubinstein shows that the American version of this option can be characterized similarly for valuation purposes.[13] It can be regarded as U_0 American options to buy an asset worth V/U for 1.0 when the risk-free interest rate is q_U and the dividend yield on the asset is q_V. The option can therefore be valued using a binomial tree.

An option to obtain the better or worse of two assets can be regarded as a position in one of the assets combined with an option to exchange it for the other asset:

$$\min(U_T, V_T) = V_T - \max(V_T - U_T, 0)$$

$$\max(U_T, V_T) = U_T + \max(V_T - U_T, 0)$$

OPTIONS INVOLVING SEVERAL ASSETS

Options involving two or more risky assets are sometimes referred to as *rainbow options*. One example is the bond futures contract traded on the CBOT described in Chapter 9. The party with the short position is allowed to choose between a large number of different bonds when making delivery.

Probably the most popular option involving several assets is a European *basket option*. This is an option where the payoff is dependent on the value of a portfolio (or basket) of assets. The assets are usually either individual stocks or stock indices or currencies. A European basket option can be valued with Monte Carlo simulation, by assuming that the assets follow correlated geometric Brownian motion processes. A much faster approach is to calculate the first two moments of the basket at the maturity of the option in a risk-neutral world, and then assume that value of the basket is lognormally distributed at that time. The option can then be valued using Black's model with the parameters shown in Equations (14.3) and (14.4). In this case,

$$M_1 = \sum_{i=1}^{n} F_i \quad \text{and} \quad M_2 = \sum_{i=1}^{n}\sum_{j=1}^{n} F_i F_j e^{\rho_{ij}\sigma_i\sigma_j T}$$

where n is the number of assets, T is the option maturity, F_i and σ_i are the forward price and volatility of the ith asset, and ρ_{ij} is the correlation between the ith and jth asset. See Technical Note 28 at www.rotman.utoronto.ca/~hull/TechnicalNotes.

VOLATILITY AND VARIANCE SWAPS

A volatility swap is an agreement to exchange the realized volatility of an asset between time 0 and time T for a prespecifed fixed volatility. The realized volatility is usually calculated with the assumption that the mean daily return is zero. Suppose that there are n daily observations on the asset price during the period between time 0 and time T. The realized volatility is

$$\bar{\sigma} = \sqrt{\frac{252}{n-2}\sum_{i=1}^{n-1}\left[\ln\frac{S_{i+1}}{S_i}\right]^2}$$

where S_i is the ith observation on the asset price. (Sometimes $n - 1$ might replace $n - 2$ in this formula.)

The payoff from the volatility swap at time T to the payer of the fixed volatility is $L_{vol}(\bar{\sigma} - \sigma_K)$, where L_{vol} is the notional principal and σ_K is the fixed volatility. Whereas an option provides a complex exposure to the asset price and volatility, a volatility swap is simpler in that it has exposure only to volatility.

A variance swap is an agreement to exchange the realized variance rate $\bar{V}$ between time 0 and time T for a prespecified variance rate. The variance rate is the square of the volatility ($\bar{V} = \bar{\sigma}^2$). Variance swaps are easier to value than volatility swaps. This is because the variance rate between time 0 and time T can be replicated using a portfolio of put and call options. The payoff from a variance swap at time T to the payer of the fixed variance rate is $L_{var}(\bar{V} - V_K)$, where L_{var} is the notional principal and V_K is the fixed variance rate. Often the notional principal for a variance swap is expressed in terms of the corresponding notional principal for a volatility swap using $L_{var} = L_{vol}/(2\sigma_K)$.

[13] See M. Rubinstein, "One for Another," *Risk*, July/August 1991: 30–32.

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Valuation of Variance Swap

Technical Note 22 at www.rotman.utoronto.ca/~hull/TechnicalNotes shows that, for any value S^* of the asset price, the expected average variance between times 0 and T is

$$\hat{E}(\bar{V}) = \frac{2}{T}\ln\frac{F_0}{S^*} - \frac{2}{T}\left[\frac{F_0}{S^*} - 1\right] + \frac{2}{T}\left[\int_{K=0}^{S^*}\frac{1}{K^2}e^{rT}p(K)dK + \int_{K=S^*}^{\infty}\frac{1}{K^2}e^{rT}c(K)dK\right] \quad (14.8)$$

where F_0 is the forward price of the asset for a contract maturing at time T, $c(K)$ is the price of a European call option with strike price K and time to maturity T, and $p(K)$ is the price of a European put option with strike price K and time to maturity T.

This provides a way of valuing a variance swap.[14] The value of an agreement to receive the realized variance between time 0 and time T and pay a variance rate of V_K, with both being applied to a principal of L_{var}, is

$$L_{var}[\hat{E}(\bar{V}) - V_K]e^{-rT} \quad (14.7)$$

Suppose that the prices of European options with strike prices $K_i (1 \le i \le n)$ are known, where $K_1 < K_2 < \ldots < K_n$. A standard approach for implementing Equation (14.6) is to set S^* equal to the first strike price below F_0 and then approximate the integrals as

$$\int_{K=0}^{S^*}\frac{1}{K^2}e^{rT}p(K)dK + \int_{K=S^*}^{\infty}\frac{1}{K^2}e^{rT}c(K)dK = \sum_{i=1}^{n}\frac{\Delta K_i}{K_i^2}e^{rT}Q(K_i) \quad (14.8)$$

where $\Delta K_i = 0.5(K_{i+1} - K_{i-1})$ for $2 \le i \le n-1$, $\Delta K_1 = K_2 - K_1$, $\Delta K_n = K_n - K_{n-1}$. The function $Q(K_i)$ is the price of a European put option with strike price K_i if $K_i < S^*$ and the price of a European call option with strike price K_i if $K_i > S^*$. When $K_i = S^*$, the function $Q(K_i)$ is equal to the average of the prices of a European call and a European put with strike price K_i.

[14] See also K. Demeterfi, E. Derman, M. Kamal, and J. Zou, "A Guide to Volatility and Variance Swaps," *The Journal of Derivatives*, 6, 4 (Summer 1999), 9–32. For options on variance and volatility, see P. Carr and R. Lee, "Realized Volatility and Variance: Options via Swaps," *Risk*, May 2007, 76–83.

Example 14.4

Consider a 3-month contract to receive the realized variance rate of an index over the 3 months and pay a variance rate of 0.045 on a principal of $100 million. The risk-free rate is 4% and the dividend yield on the index is 1%. The current level of the index is 1020. Suppose that, for strike prices of 800, 850, 900, 950, 1,000, 1,050, 1,100, 1,150, 1,200, the 3-month implied volatilities of the index are 29%, 28%, 27%, 26%, 25%, 24%, 23%, 22%, 21%, respectively. In this case, $n = 9$, $K_1 = 800$, $K_2 = 850, \ldots, K_9 = 1{,}200$, $F_0 = 1{,}020e^{(0.04-0.01)\times 0.25} = 1{,}027.68$, and $S^* = 1{,}000$. DerivaGem shows that $Q(K_1) = 2.22$, $Q(K_2) = 5.22$, $Q(K_3) = 11.05$, $Q(K_4) = 21.27$, $Q(K_5) = 51.21$, $Q(K_6) = 38.94$, $Q(K_7) = 20.69$, $Q(K_8) = 9.44$, $Q(K_9) = 3.57$. Also, $\Delta K_i = 50$ for all i. Hence,

$$\sum_{i}^{n}\frac{\Delta K_i}{K_i^2}e^{rT}Q(K_i) = 0.008139$$

From Equations (14.6) and (14.8), it follows that

$$\hat{E}(\bar{V}) = \frac{2}{0.25}\ln\left(\frac{1027.68}{1{,}000}\right) - \frac{2}{0.25}\left(\frac{1027.68}{1{,}000} - 1\right) + \frac{2}{0.25}\times 0.008139 = 0.0621$$

From Equation (14.7), the value of the variance swap (in millions of dollars) is $100 \times (0.0621 - 0.045)e^{-0.04\times 0.25} = 1.69$.

Valuation of a Volatility Swap

To value a volatility swap, we require $\hat{E}(\bar{\sigma})$, where $\bar{\sigma}$ is the average value of volatility between time 0 and time T. We can write

$$\bar{\sigma} = \sqrt{\hat{E}(\bar{V})}\sqrt{1 + \frac{\bar{V} - \hat{E}(\bar{V})}{\hat{E}(\bar{V})}}$$

Expanding the second term on the right-hand side in a series gives

$$\bar{\sigma} = \sqrt{\hat{E}(\bar{V})}\left\{1 + \frac{\bar{V} - \hat{E}(\bar{V})}{2\hat{E}(\bar{V})} - \frac{1}{8}\left[\frac{\bar{V} - \hat{E}(\bar{V})}{\hat{E}(\bar{V})}\right]^2\right\}$$

Taking expectations,

$$\hat{E}(\bar{\sigma}) = \sqrt{\hat{E}(\bar{V})}\left\{1 - \frac{1}{8}\left[\frac{\text{var}(\bar{V})}{\hat{E}(\bar{V})^2}\right]\right\} \quad (14.9)$$

where $\text{var}(\bar{V})$ is the variance of $\bar{V}$. The valuation of a volatility swap therefore requires an estimate of the variance of the average variance rate during the life of the contract.

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The value of an agreement to receive the realized volatility between time 0 and time T and pay a volatility of σ_K, with both being applied to a principal of L_{vol}, is

$$L_{vol}[\hat{E}(\bar{\sigma}) - \sigma_K]e^{-rT}$$

Example 14.5

For the situation in Example 14.4, consider a volatility swap where the realized volatility is received and a volatility of 23% is paid on a principal of $100 million. In this case $\hat{E}(\bar{V}) = 0.0621$. Suppose that the standard deviation of the average variance over 3 months has been estimated as 0.01. This means that $\text{var}(\bar{V}) = 0.0001$. Equation (14.9) gives

$$\hat{E}(\bar{\sigma}) = \sqrt{0.0621}\left(1 - \frac{1}{8} \times \frac{0.0001}{0.0621^2}\right) = 0.2484$$

The value of the swap in (millions of dollars) is

$$100 \times (0.2484 - 0.23)e^{-0.04\times 0.25} = 1.82$$

The VIX Index

In Equation (14.6), the ln function can be approximated by the first two terms in a series expansion:

$$\ln\left(\frac{F_0}{S^*}\right) = \left(\frac{F_0}{S^*} - 1\right) - \frac{1}{2}\left(\frac{F_0}{S^*} - 1\right)^2$$

This means that the risk-neutral expected cumulative variance is calculated as

$$\hat{E}(\bar{V})T = -\left(\frac{F_0}{S^*} - 1\right)^2 + 2\sum_{i=1}^{n}\frac{\Delta K_i}{K_i^2}e^{rT}Q(K_i) \qquad (14.10)$$

Since 2004 the VIX volatility index has been based on Equation (14.10). The procedure used on any given day is to calculate $\hat{E}(\bar{V})T$ for options that trade in the market and have maturities immediately above and below 30 days. The 30-day risk-neutral expected cumulative variance is calculated from these two numbers using interpolation. This is then multiplied by 365/30 and the index is set equal to the square root of the result. More details on the calculation can be found on:

www.cboe.com/micro/vix/vixwhite.pdf

STATIC OPTIONS REPLICATION

If certain procedures are used for hedging exotic options, some are easy to handle, but others are very difficult because of discontinuities (see Box 14-1). For the difficult cases, a technique known as static options replication is sometimes useful.[15] This involves searching for a portfolio of actively traded options that approximately replicates the exotic option. Shorting this position provides the hedge.[16]

BOX 14-1 Is Delta Hedging Easier or More Difficult for Exotics?

We can approach the hedging of exotic options by creating a delta neutral position and rebalancing frequently to maintain delta neutrality. When we do this we find some exotic options are easier to hedge than plain vanilla options and some are more difficult.

An example of an exotic option that is relatively easy to hedge is an average price option where the averaging period is the whole life of the option. As time passes, we observe more of the asset prices that will be used in calculating the final average. This means that our uncertainty about the payoff decreases with the passage of time. As a result, the option becomes progressively easier to hedge. In the final few days, the delta of the option always approaches zero because price movements during this time have very little impact on the payoff.

By contrast barrier options are relatively difficult to hedge. Consider a down-and-out call option on a currency when the exchange rate is 0.0005 above the barrier. If the barrier is hit, the option is worth nothing. If the barrier is not hit, the option may prove to be quite valuable. The delta of the option is discontinuous at the barrier making conventional hedging very difficult.

The basic principle underlying static options replication is as follows. If two portfolios are worth the same on a certain boundary, they are also worth the same at all interior points of the boundary. Consider as an example a 9-month up-and-out call option on a non-dividend-paying stock where the stock price is 50, the strike price is 50, the barrier is 60, the risk-free interest rate is 10% per annum, and the volatility is 30% per annum. Suppose that $f(S, t)$ is the value of the option at time t for a stock price of S. Any boundary in (S, t) space can be used for the

[15] See E. Derman, D. Ergener, and I. Kani, "Static Options Replication," *Journal of Derivatives* 2, 4 (Summer 1995): 78–95.

[16] Technical Note 22 at www.rotman.utoronto.ca/~hull/TechnicalNotes provides an example of static replication. It shows that the variance rate of an asset can be replicated by a position in the asset and out-of-the money options on the asset. This result, which leads to Equation (14.6), can be used to hedge variance swaps.

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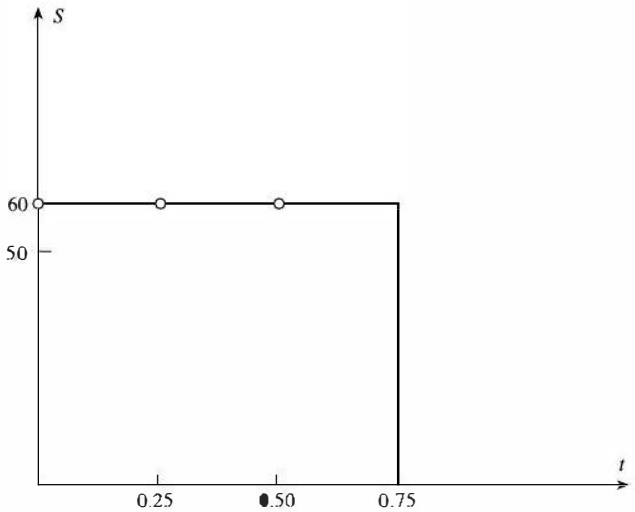

FIGURE 14-1 Boundary points used for static options replication example.

purposes of producing the replicating portfolio. A convenient one to choose is shown in Figure 14-1. It is defined by $S = 60$ and $t = 0.75$. The values of the up-and-out option on the boundary are given by

$$f(S, 0.75) = \max(S - 50, 0) \quad \text{when} \quad S < 60$$

$$f(60, t) = 0 \quad \text{when} \quad 0 \le t \le 0.75$$

There are many ways that these boundary values can be approximately matched using regular options. The natural option to match the first boundary is a 9-month European call with a strike price of 50. The first component of the replicating portfolio is therefore one unit of this option. (We refer to this option as option A.)

One way of matching the $f(60, t)$ boundary is to proceed as follows:

1. Divide the life of the option into N steps of length Δt
2. Choose a European call option with a strike price of 60 and maturity at time $N\Delta t$ (= 9 months) to match the boundary at the $\{60, (N - 1)\Delta t\}$ point
3. Choose a European call option with a strike price of 60 and maturity at time $(N - 1)\Delta t$ to match the boundary at the $\{60, (N - 2)\Delta t\}$ point

and so on. Note that the options are chosen in sequence so that they have zero value on the parts of the boundary matched by earlier options.[17] The option with a strike price of 60 that matures in 9 months has zero value on the vertical boundary that is matched by option A. The option maturing at time $i\Delta t$ has zero value at the point $\{60, i\Delta t\}$ that is matched by the option maturing at time $(i + 1)\Delta t$ for $1 \le i \le N - 1$.

Suppose that $\Delta t = 0.25$. In addition to option A, the replicating portfolio consists of positions in European options with strike price 60 that mature in 9, 6, and 3 months. We will refer to these as options B, C, and D, respectively. Given our assumptions about volatility and interest rates, option B is worth 4.33 at the {60, 0.5} point. Option A is worth 11.54 at this point. The position in option B necessary to match the boundary at the {60, 0.5} point is therefore −11.54/4.33 = −2.66. Option C is worth 4.33 at the {60, 0.25} point. The position taken in options A and B is worth −4.21 at this point. The position in option C necessary to match the boundary at the {60, 0.25} point is therefore 4.21/4.33 = 0.97. Similar calculations show that the position in option D necessary to match the boundary at the {60, 0} point is 0.28.

The portfolio chosen is summarized in Table 14-1. It is worth 0.73 initially (i.e., at time zero when the stock price is 50). This compares with 0.31 given by the analytic formula for the up-and-out call earlier in this chapter. The replicating portfolio is not exactly the same as the up-and-out option because it matches the latter at only three points on the second boundary. If we use the same procedure, but match at 18 points on the second boundary (using options that mature every half month), the value of the replicating portfolio reduces to 0.38. If 100 points are matched, the value reduces further to 0.32.

TABLE 14-1 The Portfolio of European Call Options Used to Replicate an Up-and-Out Option

Option	Strike Price	Maturity (years)	Position	Initial Value
A	50	0.75	1.00	+6.99
B	60	0.75	−2.66	−8.21
C	60	0.50	0.97	+1.78
D	60	0.25	0.28	+0.17

[17] This is not a requirement. If K points on the boundary are to be matched, we can choose K options and solve a set of K linear equations to determine required positions in the options.

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To hedge a derivative, the portfolio that replicates its boundary conditions must be shorted. The portfolio must be unwound when any part of the boundary is reached.

Static options replication has the advantage over delta hedging that it does not require frequent rebalancing. It can be used for a wide range of derivatives. The user has a great deal of flexibility in choosing the boundary that is to be matched and the options that are to be used.

SUMMARY

Exotic options are options with rules governing the payoff that are more complicated than standard options. We have discussed 15 different types of exotic options: packages, perpetual American options, nonstandard American options, gap options, forward start options, cliquet options, compound options, chooser options, barrier options, binary options, lookback options, shout options, Asian options, options to exchange one asset for another, and options involving several assets. We have discussed how these can be valued using the same assumptions as those used to derive the Black-Scholes-Merton model. Some can be valued analytically, but using much more complicated formulas than those for regular European calls and puts, some can be handled using analytic approximations, and some can be valued using extensions of numerical procedures.

Some exotic options are easier to hedge than the corresponding regular options; others are more difficult. In general, Asian options are easier to hedge because the payoff becomes progressively more certain as we approach maturity. Barrier options can be more difficult to hedge because delta is discontinuous at the barrier. One approach to hedging an exotic option, known as static options replication, is to find a portfolio of regular options whose value matches the value of the exotic option on some boundary. The exotic option is hedged by shorting this portfolio.

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Commodity Forwards and Futures

15

Learning Objectives

After completing this reading you should be able to:

- Apply commodity concepts such as storage costs, carry markets, lease rate, and convenience yield.
- Explain the basic equilibrium formula for pricing commodity forwards.
- Describe an arbitrage transaction in commodity forwards, and compute the potential arbitrage profit.
- Define the lease rate and explain how it determines the no-arbitrage values for commodity forwards and futures.
- Define carry markets, and illustrate the impact of storage costs and convenience yields on commodity forward prices and no-arbitrage bounds.
- Compute the forward price of a commodity with storage costs.
- Compare the lease rate with the convenience yield.
- Identify factors that impact gold, corn, electricity, natural gas, and oil forward prices.
- Compute a commodity spread.
- Explain how basis risk can occur when hedging commodity price exposure.
- Evaluate the differences between a strip hedge and a stack hedge, and explain how these differences impact risk management.
- Provide examples of cross-hedging, specifically the process of hedging jet fuel with crude oil and using weather derivatives.
- Explain how to create a synthetic commodity position, and use it to explain the relationship between the forward price and the expected future spot price.

Excerpt is Chapter 6 of Derivatives Markets, *Third Edition, by Robert McDonald.*

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Tolstoy observed that happy families are all alike; each unhappy family is unhappy in its own way. An analogous idea in financial markets is that financial forwards are all alike; each commodity, however, has unique economic characteristics that determine forward pricing in that market. In this chapter we will see the extent to which commodity forwards on different assets differ from each other, and also how they differ from financial forwards and futures. We first discuss the pricing of commodity contracts, and then examine specific contracts, including gold, corn, natural gas, and oil. Finally, we discuss hedging.

You might wonder about the definition of a commodity. Gerard Debreu, who won the Nobel Prize in economics, said this (Debreu, 1959, p. 28):

> A commodity is characterized by its physical properties, the date at which it will be available, and the location at which it will be available. The price of a commodity is the amount which has to be paid *now* for the (future) availability of one unit of that commodity.

Notice that with this definition, corn in July and corn in September, for example, are different commodities: They are available on different dates. With a financial asset, such as a stock, we think of the stock as being fundamentally the same asset over time.[1] The same is not necessarily true of a commodity, since it can be costly or impossible to transform a commodity on one date into a commodity on another date. This observation will be important.

In our discussion of forward pricing for financial assets we relied heavily on the fact that the price of a financial asset today is the present value of the asset at time T, less the value of dividends to be received between now and time T. It follows that the difference between the forward price and spot price of a financial asset reflects the costs and benefits of delaying payment for, and receipt of, the asset. Specifically, the forward price on a financial asset is given by

$$F_{0,T} = S_0 e^{(r-\delta)T} \tag{15.1}$$

where S_0 is the spot price of the asset, r is the continuously compounded interest rate, and δ is the continuous dividend yield on the asset. We will explore the extent to which Equation (15.1) also holds for commodities.

[1] When there are dividends, however, a share of stock received on different dates can be materially different.

INTRODUCTION TO COMMODITY FORWARDS

This section provides an overview of some issues that arise in discussing commodity forward and futures contracts. We begin by looking at some commodity futures prices. We then discuss some terms and concepts that will be important for commodities.

Examples of Commodity Futures Prices

For many commodities there are futures contracts available that expire at different dates in the future. Table 15-1 provides illustrative examples: we can examine these prices to see what issues might arise with commodity forward pricing.

First, consider corn. From May to July, the corn futures price rises from 646.50 to 653.75. This is a 2-month increase of 653.75/646.50 − 1 = 1.12%, an annual rate of approximately 7%. As a reference interest rate, 3-month LIBOR on March 17, 2011, was 0.31%, or about 0.077% for 3 months. Assuming that $\delta \geq 0$, this futures price is greater than that implied by Equation (15.1). A discussion would suggest an arbitrage strategy: Buy May corn and sell July corn. However, storing corn for 2 months will be costly, a consideration that did not arise with financial futures. Another issue arises with the December price: The price of corn falls 74.5 cents between July and December. It seems unlikely that this could be explained by a dividend. An alternative, intuitive explanation would be that the fall harvest causes the price of corn to drop, and hence the December futures price is low. But how is this explanation consistent with our results about no-arbitrage pricing of financial forwards?

If you examine the other commodities, you will see similar patterns for soybeans, gasoline, and oil. Only gold, with the forward price rising at approximately $0.70 per month (about 0.6% annually), has behavior resembling that of a financial contract.

The prices in Table 15-1 suggest that commodities are different than financial contracts. The challenge is to reconcile the patterns with our understanding of financial forwards, in which explicit expectations of future prices (and harvests!) do not enter the forward price formula.

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There are *many* more commodities with traded futures than just those in Table 15-1. You might think that a futures contract could be written on anything, but it is an interesting bit of trivia, discussed in the box below, that Federal law in the United States prohibits trading on two commodities.

TABLE 15-1 Futures Prices for Various Commodities, March 17, 2011

Expiration Month	Corn (cents/ bushel)	Soybeans (cents/ bushel)	Gasoline (cents/ gallon)	Oil (Brent) (dollars/ barrel)	Gold (dollars/ ounce)
April	—	—	2.9506	—	1404.20
May	646.50	1335.25	2.9563	114.90	1404.90
June	—	—	2.9491	114.65	1405.60
July	653.75	1343.50	2.9361	114.38	—
August	—	—	2.8172	114.11	1406.90
September	613.00	1321.00	2.8958	113.79	—
October	—	—	2.7775	113.49	1408.20
November	—	1302.25	2.7522	113.17	—
December	579.25	—	2.6444	112.85	1409.70

Data from CME Group.

Differences Between Commodities and Financial Assets

In discussing the commodity prices in Table 15-1, we invoked considerations that did not arise with financial assets, but that will arise repeatedly when we discuss commodities. Among these are:

Storage costs. The cost of storing a physical item such as corn or copper can be large relative to its value. Moreover. some commodities deteriorate over time. which is also a cost of storage. By comparison, financial securities are inexpensive to store. Consequently. we did not mention storage costs when discussing financial assets.

Carry markets. A commodity for which the forward price compensates a commodity owner

BOX 15-1 Forbidden Futures

In the United States, futures contracts on two items are explicitly prohibited by statute: onions and box office receipts for movies. Title 7, Chapter 1, §13-1 of the United States Code is titled "Violations, prohibition against dealings in onion futures; punishment" and states

> (a) No contract for the sale of onions for future delivery shall be made on or subject to the rules of any board of trade in the United States. The terms used in this section shall have the same meaning as when used in this chapter.
>
> (b) Any person who shall violate the provisions of this section shall be deemed guilty of a misdemeanor and upon conviction thereof be fined not more than $5,000.

Along similar lines, Title VII of the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 bans trading in "motion picture box office receipts (or any index, measure, value, or data related to such receipts), and all services, rights, and interests . . . in which contracts for future delivery are presently or in the future dealt in."

These bans exist because of lobbying by special interests. The onion futures ban was passed in 1959 when Michigan onion growers lobbied their new congressman, Gerald Ford, to ban such trading, believing that it depressed prices. Today, some regret the law:

> Onion prices soared 400% between October 2006 and April 2007, when weather reduced crops, according to the U.S. Department of Agriculture, only to crash 96% by March 2008 on overproduction and then rebound 300% by this past April.
>
> The volatility has been so extreme that the son of one of the original onion growers who lobbied Congress for the trading ban now thinks the onion market would operate more smoothly if a futures contract were in place.
>
> "There probably has been more volatility since the ban," says Bob Debruyn of Debruyn Produce, a Michigan-based grower and wholesaler. "I would think that a futures market for onions would make some sense today, even though my father was very much involved in getting rid of it."
>
> *Source:* Fortune magazine on-line, June 27, 2008.

Similarly, futures on movie box office receipts had been approved early in 2010 by the Commodity Futures Trading Commission. After lobbying by Hollywood interests, the ban on such trading was inserted into the Dodd-Frank financial reform bill.

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for costs of storage is called a **carry market**. (In such a market. the return on a cash-and-carry, net of all costs, is the risk-free rate.) Storage of a commodity is an economic decision that varies across commodities and that can vary over time for a given commodity. Some commodities are at times stored for later use (we will see that this is the case for natural gas and corn), others are more typically used as they are produced (oil, copper). By contrast, financial markets are always carry markets: Assets are always "stored" (owned), and forward prices always compensate owners for storage.

Lease rate. The short-seller of an item may have to compensate the owner of the item for lending. In the case of financial assets, short-sellers have to compensate lenders for missed dividends or other payments accruing to the asset. For commodities, a short-seller may have to make a payment, called a lease payment, to the commodity lender. The lease payment typically would nor correspond to dividends in the usual sense of the word.

Convenience yield. The owner of a commodity in a commodity-related business may receive nonmonetary benefits from physical possession of the commodity. Such benefits may be reflected in forward prices and are generically referred to as a **convenience yield**.

We will discuss all of these concepts in more depth later in the chapter. For now, the important thing to keep in mind is that commodities differ in important respects from financial assets.

Commodity Terminology

There are many terms that are particular to commodities and thus often unfamiliar even to those well acquainted with financial markets. These terms deal with the properties of the forward curve and the physical characteristics of commodities.

Table 15-1 illustrates two terms often used by commodity traders in talking about forward curves: **contango** and **backwardation**. If the forward curve is upward sloping—i.e., forward prices more distant in time are higher—then we say the market is in contango. We observe this pattern with near-term corn and soybeans, and with gold. If the forward curve is downward sloping, we say the market is in backwardation. We observe this with medium-term corn and soybeans, with gasoline (after 2 months), and with crude oil.

Commodities can be broadly classified as **extractive** and **renewable**. Extractive commodities occur naturally in the ground and are obtained by mining and drilling. Examples include metals (silver, gold, and copper) and hydrocarbons, including oil and natural gas. Renewable commodities are obtained through agriculture and include grains (corn, soybeans, wheat), livestock (cattle, pork bellies), dairy (cheese, milk), and lumber.

Commodities can be further classified as **primary** and **secondary**. Primary commodities are unprocessed: corn, soybeans, oil, and gold are all primary. Secondary commodities have been processed. In Table 15-1, gasoline is a secondary commodity.

Finally, commodities are measured in uncommon units for which you may not know precise definitions. Table 15-1 has several examples. A **barrel** of oil is 42 gallons. A **bushel** is a dry measure containing approximately 2150 cubic inches. The ounce used to weigh precious metals, such as gold, is a **troy ounce**, which is approximately 9.7% greater in weight than the customary avoirdupois ounce.[2]

Entire books are devoted to commodities (e.g., see Geman, 2005). Our goal here is to understand the *logic* of forward pricing for commodities and where it differs from the logic of forward pricing for financial assets. We will see that understanding a forward curve generally requires that we understand something about the underlying commodity.

EQUILIBRIUM PRICING OF COMMODITY FORWARDS

In this section we present definitions relating the prepaid forward price, forward price, and present value of a future commodity price.

[2] A troy ounce is 480 grains and the more familiar avoirdupois ounce is 437.5 grains. Twelve troy ounces make 1 troy pound, which weighs approximately 0.37 kg.

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The prepaid forward price for a commodity is the price today to receive a unit of the commodity on a future date. The prepaid forward price is therefore by definition the present value of the commodity on the future date. Hence, the prepaid forward price is

$$F^{P}_{0,T} = e^{-\alpha T} E_0[S_T] \tag{15.2}$$

where α is the discount rate for the commodity.

The forward price is the future value of the prepaid forward price, with the future value computed using the risk-free rate:

$$F_{0,T} = e^{rT} F^{P}_{0,T} \tag{15.3}$$

Substituting Equation (15.2) into Equation (15.3), we see that the commodity forward price is the expected spot price, discounted at the risk premium:

$$F_{0,T} = E_0(S_T)e^{-(\alpha - r)T} \tag{15.4}$$

We can rewrite Equation (15.4) to obtain

$$e^{-rT} F_{0,T} = E_0(S_T)e^{-\alpha T} \tag{15.5}$$

Equation (15.5) deserves emphasis: *The time-T forward price discounted at the risk-free rate is the present value of a unit of commodity received at time T*. This equation implies that, for example, an industrial producer who buys oil can calculate the present value of future oil costs by discounting oil forward prices at the risk-free rate. This calculation does not depend upon whether the producer hedges. We will see an example of this calculation later in the chapter.

PRICING COMMODITY FORWARDS BY ARBITRAGE

We now investigate no-arbitrage pricing for commodity forward contracts. We begin by using copper as an example. Copper is durable and can be stored, but it is typically not stored except as needed for production. The primary goal in this section will be to understand the issues that distinguish forward pricing for commodities from forward pricing for financial assets.

Figure 15-1 shows specifications for the CME Group copper contract and Figure 15-2 shows forward curves for copper on four dates. The copper forward curve lacks drama: For three of the four curves, the forward price in 1 year is approximately equal to the forward price in the current month. For the fourth curve, the 1-year price is below the current price (the curve exhibits backwardation).

We saw that for non-dividend-paying financial assets, the forward price rises at the interest rate. How can the

Underlying	High-grade (Grade 1) copper
Where traded	CME Group/COMEX
Size	25,000 pounds
Months	24 consecutive months
Trading ends	Third-to-last business day of the maturing month
Delivery	Exchange-designated warehouse within the United States

FIGURE 15-1 Specifications for the CME Group/COMEX high-grade copper contract.

Data from Datastream.

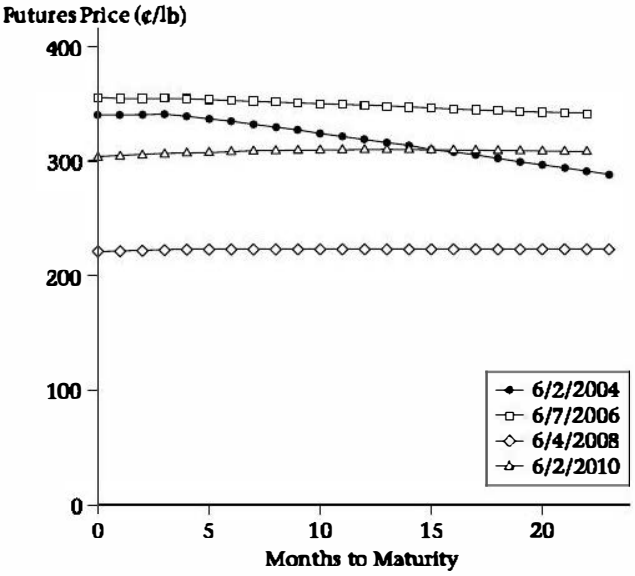

FIGURE 15-2 Forward curves for four dates for the CME Group high-grade copper futures contract.

Data from Datastream.

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forward price of copper on a future date equal the current forward price? At an intuitive level, it is reasonable to expect the price of copper in 1 year to equal the price today. Suppose, for example, that the extraction and other costs of copper production are \$3/pound and are expected to remain \$3. If demand is not expected to change, or if it is easy for producers to alter production, it would be reasonable to expect that on average the price of copper would remain at \$3. The question is how to reconcile this intuition with the behavior of forward prices for financial assets.

While it is reasonable to think that the price of copper will be expected to remain the same over the next year, it is important to recognize that a constant price would *not* be a reasonable assumption about the price of a non-dividend-paying stock. Investors must expect that a stock will on average pay a positive return, or no one would own it. In equilibrium, stocks and other financial assets must be held by investors, or *stored*. The stock price appreciates on average so that investors will willingly store the stock. There is no such requirement for copper, which can be extracted and then used in production. The equilibrium condition for copper relates to extraction, not to storage above ground. This distinction between a storage and production equilibrium is a central concept in our discussion of commodities. At the outset, then, there is an obvious difference between copper and a financial asset. It is not necessarily obvious, however, what bearing this difference has on pricing forward contracts.

An Apparent Arbitrage

Suppose that you observe that both the current price and 1-year forward price for copper are \$3.00 and that the effective annual interest rate is 10%. For the reasons we have just discussed, market participants could rationally believe that the copper price in 1 year will be \$3.00. From our discussion of financial forwards, however, you might think that the forward price should be 1.10 × \$3.00 = \$3.30, the future value of the current copper price. The \$3.00 forward price would therefore create an arbitrage opportunity.[3] If the forward price were \$3.00 you could buy copper forward and short sell copper today. Table 15-2 depicts the cash flows in this reverse cash-and-carry arbitrage. The result seems to show that there is an arbitrage opportunity for any copper forward price below \$3.30. If the copper forward price is \$3.00, it seems that you make a profit of \$0.30 per pound of copper.

TABLE 15-2 Apparent Reverse Cash-and-Carry Arbitrage for Copper If the Copper Forward Price Is $F_{0,1} <$ \$3.30. These calculations *appear* to demonstrate that there is an arbitrage opportunity if the copper forward price is below \$3.30. S_1 is the spot price of copper in 1 year, and $F_{0,1}$ is the copper forward price. There is a logical error in the table.

	Cash Flows	
Transaction	**Time 0**	**Time 1**
Long forward @ $F_{0,1}$	0	$S_1 - F_{0,1}$
Short-sell copper	+\$3.00	$-S_1$
Lend short-sale proceeds @ 10%	−\$3.00	+\$3.30
Total	0	\$3.30 − $F_{0,1}$

We seem to be stuck. Common sense suggests that a forward price of \$3.00 would be reasonable, but the transactions in Table 15-2 imply that any forward price less than \$3.30 leads to an arbitrage opportunity, where we would earn \$3.30 − $F_{0,1}$ per pound of copper.

If you are puzzled, you should stop and think before proceeding. There is a problem with Table 15-2.

The arbitrage assumes that you can short-sell copper by borrowing it today and returning it in a year. However, in order for you to short-sell for a year, there must be an investor willing to lend copper for that period. The lender must both be holding the asset and willing to give up physical possession for the period of the short-sale. A lender in this case will think: "I have spent \$3.00 for copper. Copper that I lend will be returned in 1 year. If copper at that time sells for \$3.00, then I have earned zero interest on my \$3.00 investment. If I hedge by selling copper forward for \$3.00, I will for certain earn zero interest, having bought copper for \$3.00 and then selling it for \$3.00 a year later." Conversely, from the perspective of

[3] We will discuss arbitrage in this section focusing on the forward price relative to the spot price. However, the difference between any forward prices at different dates must also reflect no-arbitrage conditions. So you can apply the discussions in this section to any two points on the forward curve.

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the short-seller, borrowing a pound of copper for a year is an arbitrage because it is an interest-free loan of $3.00. The borrower benefits and the lender loses, so *no one will lend copper without charging an additional fee*. While it is straightforward to borrow a financial asset, borrowing copper appears to be a different matter.

To summarize: The apparent arbitrage in Table 15-2 has nothing to do with mispriced forward contracts on copper. The issue is that the copper loan is equivalent to an interest-free loan, and thus generates an arbitrage profit.

Short-Selling and the Lease Rate

How do we correct the arbitrage analysis in Table 15-2? We have to recognize that the copper lender has invested $3.00 in copper and must expect to earn a satisfactory return on that investment. *The copper lender will require us to make a lease payment so that the commodity loan is a fair deal.* The actual payment the lender requires will depend on the forward price. The lender will recognize that it is possible to use the forward market to lock in a selling price for the copper in 1 year, and will reason that copper bought for $3.00 today can be sold for $F_{0,1}$ in 1 year. A copper borrower must therefore be prepared to make an extra payment—a lease payment—of

$$\text{Lease payment} = 1.1 \times \$3.00 - F_{0,1}$$

With the lender requiring this extra payment, we can correct the analysis in Table 15-2. Table 15-3 incorporates the lease payment and shows that the apparent arbitrage vanishes.

We can also interpret a lease payment in terms of discounted cash flow. Let α denote the equilibrium discount rate for an asset with the same risk as the commodity. The lender is buying the commodity for S_0. One unit returned at time T is worth S_T, with a present value of $E_0(S_T)e^{-\alpha T}$. If there is a proportional continuous lease payment of δ_l, the NPV of buying the commodity and lending it is

$$\text{NPV} = E_0(S_T)e^{-\alpha T}e^{\delta_l T} - S_0 \qquad (15.8)$$

The lease rate that makes NPV zero is then

$$\delta_l = \alpha - \frac{1}{T}\ln\left[E_0(S_T)/S_0\right]$$

The lease rate is the difference between the discount rate for the commodity and the expected price appreciation.

TABLE 15-3 Reverse Cash-and-Carry Arbitrage for Copper. This table demonstrates that there is no arbitrage opportunity if the commodity lender requires an appropriate lease payment.

	Cash Flows	
Transaction	**Time 0**	**Time 1**
Long forward @ $F_{0,1}$	0	$S_1 - F_{0,1}$
Short-sell copper	+$3.00	$-S_1$
Lease payment	0	$-(\$3.30 - F_{0,1})$
Lend short-sale proceeds @ 10%	−$3.00	+$3.30
Total	0	0

From substituting Equation (15.5) into this expression, an equivalent way to write the continuous lease rate is

$$\delta_l = r - \frac{1}{T}\ln\left[F_{0,T}/S_0\right] \qquad (15.7)$$

It is important to be clear about the reason a lease payment is required for a commodity and not for a financial asset. For a non-dividend-paying financial asset, the price is the present value of the future price, so that $S_0 = E_0(S_T)e^{-\alpha T}$. This implies that the lease payment is zero. For most commodities, the current price is not the present value of the expected future price, so there is no presumption that the lease rate would be zero.

No-Arbitrage Pricing Incorporating Storage Costs

We now consider the effects of storage costs. Storage is not always feasible (for example, fresh strawberries are perishable), and when technically feasible, storage for commodities is almost always costly. If storage is feasible, how do storage costs affect forward pricing? The intuitive answer is that if it is optimal to store the commodity, then the forward price must be high enough so that the returns on a cash-and-carry compensate for both financing and storage costs. However, if storage is not optimal, storage costs are irrelevant. We will examine both cash-and-carry and reverse cash-and-carry arbitrages to see how they are affected by storage costs.

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Cash-and-Carry Arbitrage. Put yourself in the position of a commodity merchant who owns one unit of the commodity, and ask whether you would be willing to store it until time T. You face the choice of selling it today, receiving S_0, or selling it at time T. If you guarantee your selling price by selling forward, you will receive $F_{0,T}$.

It is common sense that *you will store only if the present value of selling at time T is at least as great as that of selling today*. Denote the future value of storage costs for one unit of the commodity from time 0 to T as $\lambda(0, T)$. Table 15-4 summarizes the cash flows for a cash-and-carry with storage costs. The table shows that the cash-and-carry arbitrage is not profitable if

$$F_{0,1} < (1+R)S_0 + \lambda(0,1) \tag{15.8}$$

If inequality (15.8) is violated, storage will occur because the forward premium is great enough that sale proceeds in the future compensate for the financial costs of storage (RS_0) and the physical costs of storage ($\lambda(0, 1)$). If there is to be both storage and no arbitrage, then Equation (15.8) holds with equality. An implication of Equation (15.8) is that when costly storage occurs, the forward curve can rise faster than the interest rate. We can view storage costs as a negative dividend: Instead of receiving cash flow for holding the asset, you have to pay to hold the asset. If there is storage, storage costs increase the upper bound for the forward price. Storage costs can include depreciation of the commodity, which is less a problem for metals such as copper than for commodities such as strawberries and electricity.

TABLE 15-4 Cash-and-Carry for Copper for 1 Year, Assuming That There Is a 1-year Storage Cost of $\lambda(0, 1)$ Payable at Time 1, and an Effective Interest Rate of R

	Cash Flows	
Transaction	**Time 0**	**Time 1**
Buy copper	$-S_0$	S_1
Pay storage cost	0	$-\lambda(0, 1)$
Short forward	0	$F_{0,1} - S_1$
Borrow @ R	$+S_0$	$-(1 + R)S_0$
Total	0	$F_{0,1} - [(1 + R)S_0 + \lambda(0, 1)]$

In the special case where continuous storage costs of λ are paid continuously and are proportional to the value of the commodity, storage cost is like a continuous negative dividend. If storage occurs and there is no arbitrage, we have[4]

$$F_{0,T} = S_0 e^{(r+\lambda)T} \tag{15.9}$$

This would be the forward price in a carry market, where the commodity is stored.

Example 15.1

Suppose that the November price of corn is \$2.50/bushel, the effective monthly interest rate is 1%, and storage costs per bushel are \$0.05/month. Assuming that corn is stored from November to February, the February forward price must compensate owners for interest and storage. The future value of storage costs is

$$\$0.05 + (\$0.05 \times 1.01) + (\$0.05 \times 1.01^2)$$
$$= (\$0.05/.01) \times [1 + 0.01)^3 - 1]$$
$$= \$0.1515$$

Thus, the February forward price will be

$$2.50 \times (1.01)^3 + 0.1515 = 2.7273$$

Exercise 9 asks you to verify that this is a no-arbitrage price.

Keep in mind that just because a commodity *can* be stored does not mean that it *should* (or will) be stored. Copper is typically not stored for long periods, because storage is not economically necessary: A constant new supply of copper is available to meet demand. Thus, Equation (15.8) describes the forward price *when storage occurs*. We now consider a reverse cash-and-carry arbitrage to see what happens when the forward price is lower than in Equation (15.8).

Reverse Cash-and-Carry Arbitrage. Suppose an arbitrageur buys the commodity forward and short-sells it. We have seen that the commodity lender likely requires

[4] You might be puzzled by the different ways of representing quantities such as costs and dividends. In some cases we have used discrete values; in others, we have used continuous approximations. All of these represent the same conceptual amount (a present or future value of a cost of cash flow). You should be familiar with different ways of writing the formulas.

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a lease payment and that the payment *should* be equal to $(1 + R)S_0 - F_{0,1}$. The results of this transaction are in Table 15-5. Note first that storage costs do not affect profit because neither the arbitrageur nor the lender is actually storing the commodity. The reverse cash-and-carry is profitable if the lender requires a lease payment below $(1 + R)S_0 - F_{0,1}$. Otherwise, arbitrage is not profitable. If the commodity lender uses the forward price to determine the lease rate, then the resulting circularity guarantees that profit is zero. This is evident in Table 15-5, where profit is zero if $L = (1 + R)S_0 - F_{0,1}$.

This analysis has the important implication that the ability to engage in a reverse cash-and-carry arbitrage does not put a lower bound on the forward price. We conclude that a forward price that is too high can give rise to arbitrage, but a forward price that is too low need not.

Of course there are economic pressures inducing the forward price to reach the "correct" level. If the forward price is too low, there will be an incentive for arbitrageurs to buy the commodity forward. If it is too high, there is an incentive for traders to sell the commodity, whether or not arbitrage is feasible. Leasing and storage costs complicate arbitrage, however.

Convenience Yields

The discussion of commodities has so far ignored business reasons for holding commodities. For example, if you are a food producer for whom corn is an essential input, you will hold corn in inventory. If you hold too much corn, you can sell the excess. However, if you hold too little, you may run out of corn, halting production and idling workers and machines. The physical inventory of corn in this case has value: It provides insurance that you can keep producing in case there is a disruption in the supply of corn.

TABLE 15-5 Reverse Cash-and-Carry for Copper for 1 Year, Assuming That the Commodity Lender Requires a Lease Payment of L

	Cash Flows	
Transaction	**Time 0**	**Time 1**
Short-sell copper	S_0	$-S_1$
Lease payment	0	$-L$
Long forward	0	$S_1 - F_{0,1}$
Invest @ R	$-S_0$	$(1 + R)S_0$
Total	0	$[(1 + R)S_0 - F_{0,1}] - L$

In this situation, corn holdings provide an extra nonmonetary return called the convenience yield.[5] You will be willing to store corn with a lower rate of return than if you did not earn the convenience yield. What are the implications of the convenience yield for the forward price?

The convenience yield is only relevant when the commodity is stored. In order to store the commodity, an owner will require that the forward price compensate for the financial and physical costs of storing, but the owner will accept a lower forward price to the extent there is a convenience yield. Specifically, if the continuously compounded convenience yield is c, proportional to the value of the commodity, the owner will earn an acceptable return from storage if the forward price is

$$F_{0,T} \geq S_0 e^{(r+\lambda-c)T}$$

Because we saw that low commodity forward prices cannot easily be arbitraged, this price would not yield an arbitrage opportunity.

What is the commodity lease rate in this case? An owner lending the commodity saves λ and loses c from not storing the commodity. Hence, the commodity borrower would need to pay $\delta_l = c - \lambda$ in order to compensate the lender for convenience yield less storage cost.

The difficulty with the convenience yield in practice is that convenience is hard to observe. The concept of the convenience yield serves two purposes. First, it explains patterns in storage—for example, why a commercial user might store a commodity when the average investor will not. Second, it provides an additional parameter to better explain the forward curve. You might object that we can invoke the convenience yield to explain *any* forward curve, and therefore the concept of the

[5] The term *convenience yield* is defined differently by different authors. Convenience yield generally means a return to physical ownership of the commodity. In practice it is sometimes used to mean what we call the lease rate. In this book, the two concepts are distinct, and commodities need not have a convenience yield. The lease rate of a commodity can be inferred from the forward price using Equation (15.7).

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convenience yield is vacuous. While convenience yield can be tautological, it is a meaningful economic concept and it would be just as arbitrary to assume that there is never convenience. Moreover. the upper bound in Equation (15.8) depends on storage costs but not the convenience yield. Thus, the convenience yield only explains anomalously low forward prices, and only when there is storage.

Summary

Much of the discussion in this section was aimed at explaining the differences between commodities and financial assets. The main conclusions are intuitive:

- The forward price, $F_{0,T}$, should not exceed $S_0e^{(r+\lambda)T}$. If the forward price were greater, you could undertake a simple cash-and-carry and earn a profit after paying both storage costs and interest on the position. Storage costs here includes deterioration of the commodity, so fragile commodities could have large (or infinite) storage costs.
- In a carry market, the forward price should equal $S_0e^{(r-c+\lambda)T}$. A user who buys and stores the commodity will then be compensated for interest and physical storage costs less a convenience yield.
- In any kind of market, a reverse cash-and-carry arbitrage (attempting to arbitrage too low a forward price) will be difficult, because the terms at which a lender will lend the commodity will likely reflect the forward price, making profitable arbitrage difficult.

GOLD

Of all commodities, gold is most like a financial asset. Gold is durable, nonreactive, noncorrosive, relatively inexpensive to store (compared to its value), widely held, and actively produced through gold mining. Because of transportation costs and purity concerns, gold often trades in certificate form, as a claim to physical gold at a specific location. There are exchange-traded gold futures, specifications for which are in Figure 15-3.

Figure 15-4 graphs futures prices for all available gold futures contracts—the forward curve—for four different dates. The forward curves all show the forward price steadily increasing with time to maturity.

Underlying	Refined gold bearing approved refiner stamp
Where traded	CME Group/NYMEX
Size	100 troy ounces
Months	February, April, August, October, out 2 years. June, December, out 5 years
Trading ends	Third-to-last business day of maturity month
Delivery	Any business day of the delivery month

FIGURE 15-3 Specifications for the CME Group gold futures contract.

Data from Datastream.

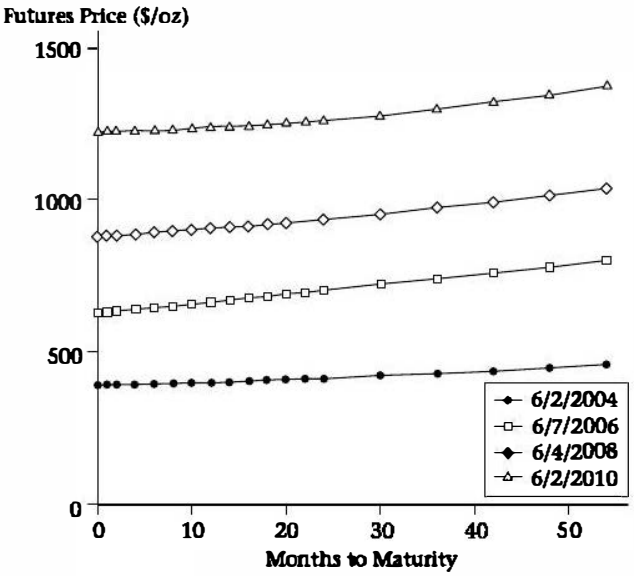

FIGURE 15-4 The forward curve for gold on four dates, from NYMEX gold futures prices.

Data from Datastream.

Gold Leasing

From our discussion in the previous section, the forward price implies a lease rate for gold. Short sales and loans of gold are in fact common in the gold market. On the lending

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side, large gold holders (including some central banks) put gold on deposit with brokers, in order that it may be loaned to short-sellers. The gold lenders earn the lease rate.

The lease rate for gold, silver, and other commodities is typically reported using Equation (15.7), with LIBOR as the interest rate. In recent years the lease rate has often been negative, especially for periods of 6 months or less.

As an example of the lease rate computation, consider gold prices on June 2, 2010. The June, December, and June 2011 futures settlement prices that day were 1220.6, 1226.8, and 1234.3. The return from buying June gold and selling December gold would have been

$$\text{Return}_{6\text{ months}} = \frac{1226.8}{1220.6} - 1 = 0.00508$$

At the same time. June LIBOR was 99.432 and September LIBOR was 99.2, so the implied 6-month interest rate was (1 + 0.00568/4) × (1 + 0.008/4), a 6-month interest rate of 0.00342. Because the (nonannualized) implied 6-month gold appreciation rate exceeds (nonannualized) 6-month LIBOR, the lease rate is negative. The annualized lease rate in this calculation is

$$2 \times (0.00342 - 0.00508) = -0.003313$$

The negative lease rate seems to imply that gold owners would pay to lend gold. With significant demand in recent years for gold storage, the negative lease rate could be measuring increased marginal storage costs. It is also possible that LIBOR is not the correct interest rate to use in computing the lease rate. Whatever the reason for negative lease rates, gold in recent years has been trading at close to full carry.

Evaluation of Gold Production

Suppose we wish to compute the present value of future production for a proposed gold mine. As discussed earlier, the present value of a unit of commodity received in the future is simply the present value of the forward price, with discounting performed at the risk-free rate. We can thus use the forward curve for gold to compute the value of an operating gold mine.

Suppose that at times t_i, $i = 1, \ldots, n$, we expect to extract n_{t_i} ounces of gold by paying a per-unit extraction cost of $x(t_i)$. We have a set of n forward prices, F_{0,t_i}. If the continuously compounded annual risk-free rate from time 0 to t_i is $r(0, t_i)$, the value of the gold mine is

$$\text{PV gold production} = \sum_{i=1}^{n} n_{t_i}\left[F_{0,t_i} - x(t_i)\right]e^{-r(0,t_i)t_i} \qquad (15.10)$$

This equation assumes that the gold mine is certain to operate the entire time and that the quantity of production is known. Only price is uncertain. Note that in Equation (15.10), by computing the present value of the forward price, we compute the prepaid forward price.

Example 15.2

Suppose we have a mining project that will produce 1 ounce of gold every year for 6 years. The cost of this project is $1100 today, the marginal cost per ounce at the time of extraction is $100, and the continuously compounded interest rate is 6%.

We observe the gold forward prices in the second column of Table 15-6, with implied prepaid forward prices in the third column. Using Equation (15.10), we can use these prices to perform the necessary present value calculations.

$$\text{Net present value} = \sum_{i=1}^{6}\left[F_{0,i} - 100\right]e^{-0.06 \times i} \qquad (15.11)$$

$$- \$1100 = \$119.56$$

TABLE 15-6 Gold Forward and Prepaid Forward Prices on 1 Day for Gold Delivered at 1-year Intervals, out to 6 Years. The continuously compounded interest rate is 6% and the lease rate is assumed to be a constant 1.5%.

Expiration Year	Forward Price ($)	Prepaid Forward Price ($)
1	313.81	295.53
2	328.25	291.13
3	343.36	286.80
4	359.17	282.53
5	375.70	278.32
6	392.99	274.18

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CORN

Important grain futures in the United States include corn, soybeans, and wheat. In this section we discuss corn as an example of an agricultural product. Corn is harvested primarily in the fall, from September through November. The United States is a leading corn producer, generally exporting rather than importing corn. Figure 15-5 presents specifications for the CME Group corn futures contract.

Given seasonality in production, what should the forward curve for corn look like? Corn is produced at one time of the year, but consumed throughout the year. In order to be consumed when it is not being produced, corn must be stored.

As discussed, storage is an economic decision in which there is a trade-off between selling today and selling tomorrow. If we can sell corn today for $2/bu and in 2 months for $2.25/bu, the storage decision entails comparing the price we can get today with the present value of the price we can get in 2 months. In addition to interest, we need to include storage costs in our analysis.

An equilibrium with some current selling and some storage requires that corn prices be expected to rise at the interest rate plus storage costs, which implies that there will be an upward trend in the price between harvests. While corn is being stored, the forward price should behave as in Equation (15.9), rising at interest plus storage costs.

Underlying	#2 Yellow, with #1 Yellow deliverable at a $0.015 premium and #3 Yellow at a $0.015 discount
Where traded	CME Group/CBOT
Size	5000 bushels (~127 metric tons)
Months	March, May, July, September, and December, out 2 years
Trading ends	Business day prior to the 15th day of the month
Delivery	Second business day following the last trading day of the delivery month

FIGURE 15-5 Specifications for the CME Group/CBOT corn futures contract.

In a typical year, once the harvest begins, storage is no longer necessary; if supply and demand remain constant from year to year, the harvest price will be the same every year. Those storing corn will plan to deplete inventory as harvest approaches and to replenish inventory from the new harvest. The corn price will fall at harvest, only to begin rising again after the harvest.

The behavior of the corn forward price, graphed in Figure 15-6, largely conforms with this description. In three of the four forward curves, the forward price of corn rises to reward storage between harvests, and it falls at harvest. An important caveat is that the supply of corn varies from year to year. When there is an unusually large crop, producers will expect corn to be stored not just over the current year but into the next year as well. If there is a large harvest, therefore, we might see the forward curve rise continuously until year 2. This might explain the low price and steady rise in 2006.

Although corn prices vary throughout the year, farmers will plant in anticipation of receiving the harvest price. It is therefore the harvest price that guides production decisions. The price during the rest of the year should approximately equal the harvest price plus storage, less convenience.

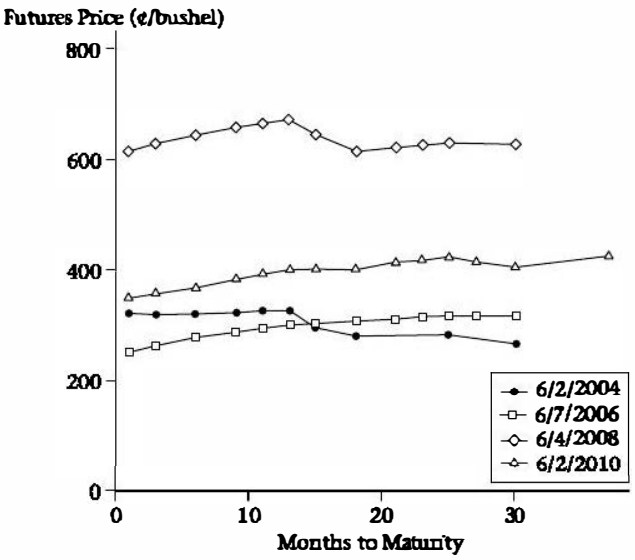

FIGURE 15-6 Forward curves for corn for four years.

Data from Datastream.

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ENERGY MARKETS

One of the most important and heavily traded commodity sectors is energy. This sector includes oil, oil products (heating oil and gasoline), natural gas, and electricity. These products represent different points on the spectrum of storage costs and carry.

Electricity

The forward market for electricity illustrates forward pricing when storage is often not possible, or at least quite costly. Electricity is produced in different ways: from fuels such as coal and natural gas, or from nuclear power, hydroelectric power, wind power, or solar power. Once it is produced, electricity is transmitted over the power grid to end-users.

There are several economic characteristics of electricity that are important to understand. First, it is difficult to store; hence it must be consumed when it is produced or else it is wasted.[6] Second, at any point in time the maximum supply of electricity is fixed. You can produce less but not more. Third, demand for electricity varies substantially by season, by day of week, and by time of day. Because carry is limited and costly, the electricity price at any time is set by demand and supply at that time.

To illustrate the effects of nonstorability, Table 15-7 displays 1-day-ahead hourly prices for 1 megawatt-hour of electricity in New York City. The 1-day-ahead forward price is $32.22 at 2 A.M. and $63.51 at 7 P.M. Ideally one would buy 2 A.M. electricity, store it, and sell it at 7 P.M., but there is no way to do so costlessly.

Notice two things. First, the swings in Table 15-7 could not occur with financial assets, which are stored. The 3 A.M. and 3 P.M. forward prices for a stock will be almost identical; if they were not, it would be possible to arbitrage the difference. Second, whereas the forward price for a stock is largely redundant in the sense that it reflects information about the current stock price, interest, and the dividend yield, the forward prices in Table 15-7 provide **price discovery**, revealing otherwise unobtainable information about the future price of the commodity. The prices in Table 15-7 are best interpreted using Equation (15.4).

Just as intraday arbitrage is difficult, there is no costless way to buy winter electricity and sell it in the summer, so there are seasonal variations as well as intraday variations. Peak-load power plants operate only when prices are high, temporarily increasing the supply of electricity. However, expectations about supply, storage, and peak-load power generation should already be reflected in the forward price.

Natural Gas

Natural gas is a market in which seasonality and storage costs are important. The natural gas futures contract, introduced in 1990, has become one of the most heavily

[6] There are costly ways to store electricity. Three examples are *pumped storage hydroelectricity* (pump water into an uphill reservoir when prices are low, and release the water to flow over turbines when electricity is expensive); *night wind storage* (refrigerated warehouses are cooled to low temperature when electricity is cheap and the temperature is allowed to rise when electricity is expensive); *compressed air energy storage* (use wind power to compress air, then use the compressed air to drive turbines when electricity is expensive). All three of these methods entail losses.

TABLE 15-7 Day-Ahead Price, by Hour, for 1 Megawatt-Hour of Electricity in New York City, March 21, 2011

Time	Price	Time	Price	Time	Price	Time	Price
0000	$36.77	0600	$44.89	1200	$53.84	1800	$56.18
0100	$34.43	0700	$58.05	1300	$51.36	1900	$63.51
0200	$32.22	0800	$52.90	1400	$50.01	2000	$54.99
0300	$32.23	0900	$54.06	1500	$49.55	2100	$47.01
0400	$32.82	1000	$55.06	1600	$49.71	2200	$40.26
0500	$35.84	1100	$55.30	1700	$51.66	2300	$37.29

Data from Bloomberg.

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Underlying	Natural gas delivered at Sabine Pipe Lines Co.'s Henry Hub, Louisiana
Where traded	New York Mercantile Exchange
Size	10,000 million British thermal units (MMBtu)
Months	72 consecutive months
Trading ends	Third-to-last business day of month prior to maturity month
Delivery	As uniformly as possible over the delivery month

FIGURE 15-7 Specifications for the NYMEX Henry Hub natural gas contract.

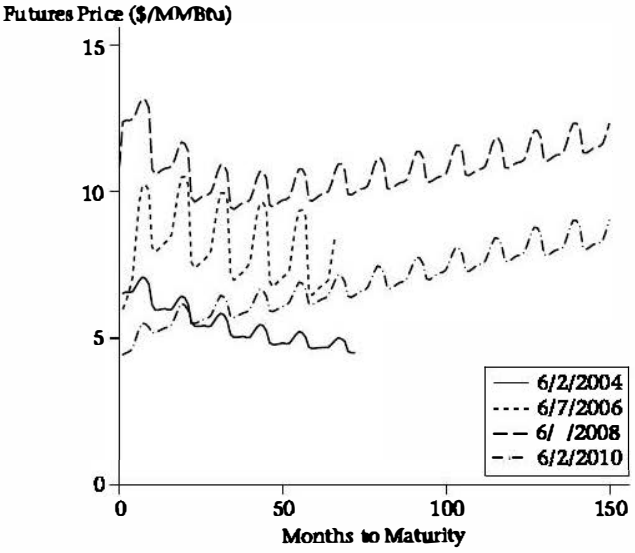

FIGURE 15-8 Forward curves for natural gas for four years. Prices are dollars per MMBtu, from CME Group/NYMEX.

Data from Datastream.

traded futures contracts in the United States. The asset underlying one contract is 10,000 MMBtu, delivered over one month at a specific location (different gas contracts call for delivery at different locations). Figure 15-7 details the specifications for the Henry Hub contract.

Natural gas has several interesting characteristics. First, gas is costly to transport internationally, so prices and forward curves vary regionally. Second, once a given well has begun production, gas is costly to store. Third, demand for gas in the United States is highly seasonal, with peak demand arising from heating in winter months. Thus, there is a relatively steady stream of production with variable demand, which leads to large and predictable price swings. Whereas corn has seasonal production and relatively constant demand, gas has relatively constant supply and seasonal demand.

Figure 15-8 displays strips of gas futures prices for the first Wednesday in June for 4 years between 2004 and 2010. In all curves, seasonality is evident, with high winter prices and low summer prices. The 2004 and 2006 strips show seasonal cycles combined with a downward trend in prices, suggesting that the market considered prices in that year as anomalously high. For the other years, the long-term trend is upward.

Gas storage is costly and demand for gas is highest in the winter. The steady rise of the forward curve (contango) during the fall months suggests that storage occurs just before the heaviest demand. In the June 2006 forward curve, the October, November, and December 2006 prices were $7.059, $8.329, and $9.599. The interest rate at that time was about 5.5%, or 0.5%/month. Interest costs would thus contribute at most a few cents to contango. Considering the October and November prices, in a carry market, storage cost would have to satisfy Equation (15.8):

$$8.329 = 7.059e^{0.005} + \lambda$$

This calculation implies an estimated expected marginal storage cost of $\lambda = \$1.235$ in November 2006. The technologies for storing gas range from pumping it into underground storage facilities to freezing it and storing it offshore in liquified natural gas tankers. By examining Figure 15-8 you will find different imputed storage costs in each year; but this is to be expected if marginal storage costs vary with the quantity stored.

Because of the expense in transporting gas internationally, the seasonal behavior of the forward curve can vary in different parts of the world. In tropical areas where gas is used for cooking and electricity generation, the forward curve is relatively flat because demand is relatively flat. In the Southern hemisphere, where seasons are reversed from the Northern hemisphere, the forward

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Underlying	Specific domestic crudes delivered at Cushing, Oklahoma
Where traded	New York Mercantile Exchange
Size	1000 U.S. barrels (42,000 gallons)
Months	30 consecutive months plus long-dated futures out 7 years
Trading ends	Third-to-last business day preceding the 25th calendar day of month prior to maturity month
Delivery	As uniformly as possible over the delivery month

FIGURE 15-9 Specifications for the NYMEX light sweet crude oil contract.

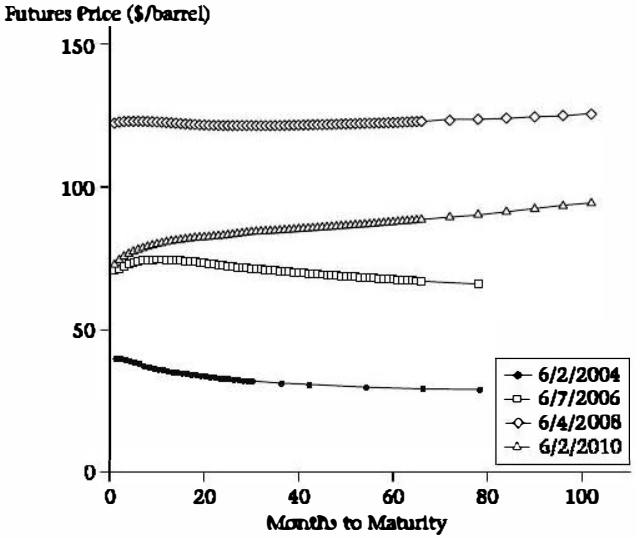

FIGURE 15-10 Multi-year strips of NYMEX crude oil futures prices, $/barrel, for four different dates.

Data from Datastream.

curve will peak in June and July rather than December and January.

Oil

Both oil and natural gas produce energy and are extracted from wells, but the different physical characteristics and uses of oil lead to a very different forward curve than that for gas. Oil is easier to transport than gas, with the result that oil trades in a global market. Oil is also easier to store than gas. Thus, seasonals in the price of crude oil are relatively unimportant. Specifications for the NYMEX light sweet crude oil contract (also known as West Texas Intermediate, or WTI) are shown in Figure 15-9.[7] The NYMEX forward curve on four dates is plotted in Figure 15-10.

On the four dates in the figure, near-term oil prices range from $40 to $125. At each price, the forward curves are relatively flat. In 2004, it appears that the market expected oil prices to decline. Obviously, that did not happen. In 2006 and 2008, the early part of the forward curve is steeply sloped, suggesting that there was a return to storage and a temporary surplus supply. During 2009, for example, there was substantial arbitrage activity with traders storing oil on tankers. This is discussed in Box 15-2.

Although oil is a global market, the delivery point for the WTI oil contract is Cushing, Oklahoma, which is landlocked. Another important oil contract is the Brent crude oil contract, based on oil from the North Sea. Historically WTI and Brent traded within a few dollars of each other, and they are of similar quality. In early 2011, however, the price of Brent was at one point almost $20/barrel greater than the price of WTI. Though there is no one accepted explanation for this discrepancy, the difficulty of transporting oil from Cushing to ports undoubtedly plays a role, and the WTI contract in recent years has lost favor as a global oil benchmark. In particular, in 2009 Saudi Arabia dropped WTI from its export benchmarks. The WTI-Brent price discrepancy illustrates the importance of transportation costs even in an integrated global market.

Oil Distillate Spreads

Some commodities are inputs in the creation of other commodities, which gives rise to **commodity spreads**. Crude oil is refined to make petroleum products, in particular heating oil and gasoline. The refining process entails distillation, which separates crude oil into different components, including gasoline, kerosene, and heating oil. The split of oil into these different components can be complemented

[7] Oil is called "sweet" if it has a relatively low sulfur content, and "sour" if the sulfur content is high.

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BOX 15-2 Tanker-Based Arbitrage

From *The Wall Street Journal:* The huge floating stockpile of crude oil kept on tankers amid a global supply glut is showing signs of shrinking, as traders struggle to make profits from the once highly lucrative storage play.

The volume being stored at sea has nearly halved from a peak of about 90 million barrels in April last year, according to ship broker ICAP, and [is] expected to fall even further. . . .

The phenomenon of floating storage took off early last year. Oil on the spot market traded at a big discount to forward-dated contracts, in a condition known as contango. Traders took advantage of that by buying crude and putting it into storage on tankers for sale at a higher price at a future date. Profits from the trade more than covered the costs of storage.

At its peak in April last year, there were about 90 million barrels of crude oil in floating storage on huge tankers known as very large crude carriers, or VLCCs, according to ICAP.

But the spread between prompt crude-oil prices and forward prices has narrowed in recent weeks, while freight rates have increased, reducing the incentive to store oil for future delivery.

Contango has narrowed to around 40 cents a barrel, and "to cover your freight and other costs you need at least 90 cents," said Torbjorn Kjus, an oil analyst at DnB NOR Markets.

J.P. Morgan has said prices could even go into backwardation at the end of the second quarter, where spot prices are higher than those in forward contracts. This would be the first time the spread has been in positive territory since July last year.

ICAP said there were currently 21 trading VLCCs offshore with some 43 million barrels of crude. Seven of these are expected to discharge in February and one more in March. So far, it appeared those discharged cargoes wouldn't be replaced by new ones. . . .

Source: Chazan (2010)

by a process known as "cracking"; hence, the difference in price between crude oil and equivalent amounts of heating oil and gasoline is called the **crack spread**.[a]

Oil can be processed in different ways, producing different mixes of outputs. The spread terminology identities the number of gallons of oil as input, and the number of gallons of gasoline and heating oil as outputs. Traders will speak of "5-3-2," "3-2-1," and "2-1-1" crack spreads. The 5-3-2 spread, for example, reflects the profit from taking 5 gallons of oil as input, and producing 3 gallons of gasoline and 2 gallons of heating oil. A petroleum refiner producing gasoline and heating oil could use a futures crack spread to lock in both the cost of oil and output prices. This strategy would entail going long oil futures and short the appropriate quantities of gasoline and heating oil futures. Of course there are other inputs to production and it is possible to produce other outputs, such as jet fuel, so the crack spread is not a perfect hedge.

Example 15.3

A refiner in June 2010 planning for July production could have purchased July oil for \$72.86/barrel and sold August gasoline and heating oil for \$2.0279/gallon and \$2.0252/gallon. The 3-2-1 crack spread is the gross margin from buying 3 gallons of oil and selling 2 gallons of gasoline and 1 of heating oil. Using these prices, the spread is

$$2 \times \$2.0279 + \$2.0252 - 3 \times \$72.86/42 = \$0.8767$$

or \$0.8767/3 = \$0.29221/gallon.

There are crack spread swaps and options. Most commonly these are based on the difference between the price of heating oil and crude oil, and the price of gasoline and heating oil, both in a 1:1 ratio.

[a] Spreads are also important in agriculture. Soybeans, for example, can be crushed to produce soybean meal and soybean oil (and a small amount of waste). A trader with a position in soybeans and an opposite position in equivalent quantities of soybean meal and soybean oil has a **crush spread** and is said to be "trading the crush."

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HEDGING STRATEGIES

In this section we discuss some issues when using commodity futures and forwards to hedge commodity price exposure. First, since commodities are heterogeneous and often costly to transport and store, it is common to hedge a risk with a commodity contract that is imperfectly correlated with the risk being hedged. This gives rise to *basis risk*: The price of the commodity underlying the futures contract may move differently than the price of the commodity you are hedging. For example, because of transportation cost and time, the price of natural gas in California may differ from that in Louisiana, which is the location underlying the principal natural gas futures contract (see again Figure 15-7). Second, in some cases one commodity may be used to hedge another. As an example of this we discuss the use of crude oil to hedge jet fuel. Finally, weather derivatives provide another example of an instrument that can be used to cross-hedge. We discuss degree-day index contracts as an example of such derivatives.

Basis Risk

Exchange-traded commodity futures contracts call for delivery of the underlying commodity at specific locations and specific dates. The actual commodity to be bought or sold may reside at a different location and the desired delivery date may not match that of the futures contract. Additionally, the *grade* of the deliverable under the futures contract may not match the grade that is being delivered.

This general problem of the futures or forward contract not representing exactly what is being hedged is called *basis risk.* Basis risk is a generic problem with commodities because of storage and transportation costs and quality differences. Basis risk can also arise with financial futures, as for example when a company hedges its own borrowing cost with the Eurodollar contract.

We demonstrated how an individual stock could be hedged with an index futures contract. We saw that if we regressed the individual stock return on the index return, the resulting regression coefficient provided a hedge ratio that minimized the variance of the hedged position.

In the same way, suppose we wish to hedge oil delivered on the East Coast with the NYMEX oil contract, which calls for delivery of oil in Cushing, Oklahoma. The variance-minimizing hedge ratio would be the regression coefficient obtained by regressing the East Coast price on the Cushing price. Problems with this regression are that the relationship may not be stable over time or may be estimated imprecisely.

Another example of basis risk occurs when hedgers decide to hedge distant obligations with near-term futures. For example, an oil producer might have an obligation to deliver 100,000 barrels per month at a fixed price for a year. The natural way to hedge this obligation would be to buy 100,000 barrels per month, locking in the price and supply on a month-by month basis. This is called a **strip hedge**. We engage in a strip hedge when we hedge a stream of obligations by offsetting each individual obligation with a futures contract matching the maturity and quantity of the obligation. For the oil producer obligated to deliver every month at a fixed price, the hedge would entail buying the appropriate quantity each month, in effect taking a long position in the strip.

An alternative to a strip hedge is a **stack hedge**. With a stack hedge, we enter into futures contracts with a *single* maturity, with the number of contracts selected so that changes in the *present value* of the future obligations are offset by changes in the value of this "stack" of futures contracts. In the context of the oil producer with a monthly delivery obligation, a stack hedge would entail going long 1.2 million barrels using the near-term contract. (Actually, we would want to tail the position and go long fewer than 1.2 million barrels, but we will ignore this.) When the near-term contract matures, we reestablish the stack hedge by going long contracts in the new near month. This process of stacking futures contracts in the near-term contract and rolling over into the new near-term contract is called a **stack and roll**. If the new near-term futures price is below the expiring near-term price (i.e., there is backwardation), rolling is profitable.

There are at least two reasons for using a stack hedge. First, there is often more trading volume and liquidity in near-term contracts. With many commodities, bid-ask spreads widen with maturity. Thus, a stack hedge may have lower transaction costs than a strip hedge. Second, the manager may wish to speculate on the shape

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of the forward curve. You might decide that the forward curve looks unusually steep in the early months. If you undertake a stack hedge and the forward curve then flattens, you will have locked in all your oil at the relatively cheap near-term price, and implicitly made gains from not having locked in the relatively high strip prices. However, if the curve becomes steeper, it is possible to lose.

Box 15-3 recounts the story of Metallgesellschaft A. G. (MG), in which MG's large losses on a hedged position might have been caused, at least in part, by the use of a stack hedge.

Hedging Jet Fuel with Crude Oil

Jet fuel futures do not exist in the United States, but firms sometimes hedge jet fuel with crude oil futures along with futures for related petroleum products. In order to perform this hedge, it is necessary to understand the relationship between crude oil and jet fuel prices. If we own a quantity of jet fuel and hedge by holding H crude oil futures contracts, our mark-to-market profit depends on the change in the jet fuel price and the change in the futures price:

$$(P_t - P_{t-1}) + H(F_t - F_{t-1}) \qquad \textbf{(15.12)}$$

where P_t is the price of jet fuel and F_t the crude oil futures price. We can estimate H by regressing the change in the jet fuel price (denominated in dollars per gallon) on the change in the crude oil futures price (denominated in dollars per gallon, which is the barrel price divided by 42). We use the nearest to maturity oil futures contract. Running this regression using daily data for January 2006–March 2011 gives[9]

$$P_t - P_{t-1} = \underset{(0.0009)}{0.0004} + \underset{(0.0192)}{0.8379}\left(F_t^{oil} - F_{t-1}^{oil}\right) \quad R^2 = 0.596 \qquad \textbf{(15.13)}$$

Standard errors are below coefficients. The coefficient on the futures price change tells us that, on average, when the crude futures price increases by \$0.01, a gallon of jet fuel increases by \$0.008379.[10] The R^2 of 0.596 implies a correlation coefficient of about 0.77, so there is considerable variation in the price of jet fuel not accounted for by the price of crude. Because jet fuel is but one product produced from crude oil, it makes sense to see if adding other oil products to the regression improves the accuracy of the hedge. Adding the near term futures prices for heating oil and gasoline, we obtain

$$\begin{aligned} P_t - P_{t-1} &= \underset{(0.0007)}{0.0006} + \underset{(0.0278)}{0.0897}\left(F_t^{oil} - F_{t-1}^{oil}\right) \\ &+ \underset{(0.0277)}{0.8476}\left(F_t^{heating\ oil} - F_{t-1}^{heating\ oil}\right) \\ &+ \underset{(0.0222)}{0.0069}\left(F_t^{gasoline} - F_{t-1}^{gasoline}\right) \quad R^2 = 0.786 \qquad \textbf{(15.14)} \end{aligned}$$

The explanatory power of the regression is improved, with an implied correlation of 0.886 between the actual and predicted jet fuel price. The price of heating oil is more closely related to the price of jet fuel than is the price of crude oil.

Weather Derivatives

Many businesses have revenue that is sensitive to weather: Ski resorts are harmed by warm winters, soft drink manufacturers are harmed by a cold spring, summer, or fall, and makers of lawn sprinklers are harmed by wet summers. In all of these cases, firms could hedge their risk using **weather derivatives**—contracts that make payments based upon realized characteristics of weather—to cross-hedge their specific risk.

Weather can affect both the price and consumption of energy-related products. If a winter is colder than average, homeowners and businesses will consume extra electricity, heating oil, and natural gas, and the prices of these products will tend to be high as well. Conversely, during a warm winter, energy prices and quantities will be low. While it is possible to use futures markets to hedge prices of commodities such as natural gas, hedging the quantity is more difficult. Weather derivatives can provide an additional contract with a payoff correlated with the quantity of energy used.

[9] This regression omits 4 days: September 11, 12, 15, and 16, 2008. The reported price of jet fuel on those days—a stressful period during the financial crisis—increased by over \$1/gallon and then on September 17 returned to its previous price.

[10] Recall that we estimated a hedge ratio for stocks using a regression based on percentage changes. In that case, we had an economic reason (an asset pricing model) to believe that there was a stable relationship based upon rates of return. In this case, crude is used to produce jet fuel, so it makes sense that dollar changes in the price of crude would be related to dollar changes in the price of jet fuel.

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BOX 15-3 Metallgesellschaft A. G.

In 1992, a U.S. subsidiary of the Gennan industrial firm Metallgesellschaft A. G. (MG) had offered customers fixed prices on over 150 million barrels of petroleum products, including gasoline, heating oil, and diesel fuel, over periods as long as 10 years. To hedge the resulting short exposure, MG entered into futures and swaps.

Much of MG's hedging was done using short-dated NYMEX crude oil and heating oil futures. Thus, MG was using stack hedging, rolling over the hedge each month.

During much of 1993, the near-term oil market was in contango (the forward curve was upward sloping). As a result of the market remaining in contango, MG systematically lost money when rolling its hedges and had to meet substantial margin calls. In December 1993, the supervisory board of MG decided to liquidate both its supply contracts and the futures positions used to hedge those contracts. In the end, MG sustained losses estimated at between $200 million and $1.3 billion.

The MG case was extremely complicated and has been the subject of pointed exchanges among academics—see in particular Culp and Miller (1995), Edwards and Canter (1995), and Mello and Parsons (1995). While the case is complicated, several issues stand out. First, was the stack and roll a reasonable strategy for MG to have undertaken? Second, should the position have been liquidated when and in the manner it was? (As it turned out, oil prices increased—which would have worked in MG's favor—following the liquidation.) Third, did MG encounter liquidity problems from having to finance losses on its hedging strategy? While the MG case has receded into history, hedgers still confront the issues raised by this case.

An example of a weather contract is the degree-day index futures contract traded at the CME Group. The contract is based on the premise that heating is used when temperatures are below 65 degrees and cooling is used when temperatures are above 65 degrees. Thus, a **heating degree-day** is the difference between 65 degrees Fahrenheit and the average daily temperature, if positive, or zero otherwise. A **cooling degree-day** is the difference between the average daily temperature and 65 degrees Fahrenheit, if positive, and zero otherwise. The monthly degree-day index is the sum of the daily degree-days over the month. The futures contract then settles based on the cumulative heating or cooling degree-days (the two are separate contracts) over the course of a month. The size of the contract is $100 times the degree-day index. Degree-day index contracts are available for major cities in the United States, Europe, and Japan. There are also puts and calls on these futures.

With city-specific degree-day index contracts, it is possible to create and hedge payoffs based on average temperatures, or using options, based on ranges of average temperatures. If Minneapolis is unusually cold but the rest of the country is normal, the heating degree-day contract for Minneapolis will make a large payment that will compensate the holder for the increased consumption of energy.

SYNTHETIC COMMODITIES

Just as it is possible to use stock index futures to create a synthetic stock index, it is also possible to use commodity futures to create synthetic commodities. We can create a synthetic commodity by combining a commodity forward contract and a zero-coupon bond. Enter into a long commodity forward contract at the price $F_{0,T}$ and buy a zero-coupon bond that pays $F_{0,T}$ at time T. Since the forward contract is costless, the cost of this investment strategy at time 0 is just the cost of the bond, which equals the prepaid forward price: $e^{-rT}F_{0,T}$. At time T, the strategy pays

$$\underbrace{S_T - F_{0,T}}_{\text{Forward contract pay off}} + \underbrace{F_{0,T}}_{\text{Bond payoff}} = S_T$$

where S_T is the time T price of the commodity. This investment strategy creates a *synthetic commodity*, which has the same value as a unit of the commodity at time T.

During the early 2000s, indexed commodity investing became popular. Commodity funds use futures contracts and Treasury bills or other bonds to create synthetic commodities and replicate published commodity indexes. Two important indexes are the S&P GSCI index (originally created by Goldman Sachs) and the Dow Jones UBS index (originally created by AIG). Masters (2008) estimates

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that money invested in commodity funds grew 20-fold between 2003 and 2008, from $13 billion to $260 billion.[11] During this same period, commodity prices rose significantly. Figure 15-11 shows the performance of two commodity indexes plotted with the S&P 500. The two indexes diverge sharply in 2009 because they weight commodities differently. The S&P GSCI index, for example, is world-production weighted and more heavily weights the petroleum sector. The DJ UBS index is designed to be more evenly weighted.[12]

You might wonder whether a commodity fund should use futures contracts to create synthetic commodities, or whether the fund should hold the physical commodity (where feasible). An important implication of the earlier discussion is that it is generally preferable to invest in synthetic commodities rather than physical commodities. To see this, we can compare the returns to owning the physical commodity and owning a synthetic commodity. As before, let $\lambda(0, T)$ denote the future value of storage costs.

To invest in the physical commodity for 1 year, we can buy the commodity and prepay storage costs. This costs $S_0 + \lambda(0, 1)/(1 + R)$ initially and one period later pays $S_1 + \lambda(0, 1) - \lambda(0, 1) = S_1$.

An investment in the synthetic commodity costs the present value of the forward price, $F_{0,1}/1 + R)$, and pays S_1. The synthetic investment will be preferable if

$$F_{0,1} / (1 + R) < S_0 + \lambda(0, 1) / (1 + R)$$

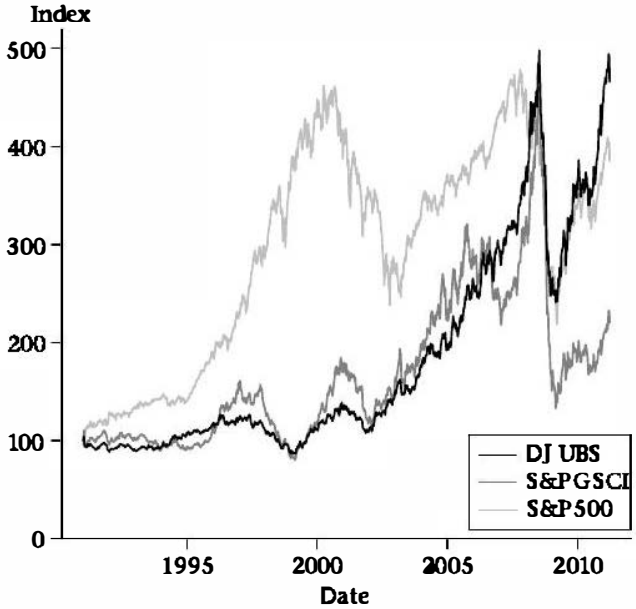

FIGURE 15-11 Value of S&P GSCI and DJ UBS indexes from 1991 to 2011, plotted against the S&P 500 index.

Source: Datastream.

or $F_{0,1} < S_0(1 + R) + \lambda(0, 1)$. Suppose, however, that $F_{0,1} > S_0(1 + R) + \lambda(0, 1)$. This is an arbitrage opportunity exploitable by buying the commodity, storing it, paying storage costs, and selling it forward. Thus, if there is no arbitrage, we expect that $F_{0,1} \leq S_0(1 + R) + \lambda(0, 1)$ and the synthetic commodity will be the less expensive way to obtain the commodity return. Moreover, there will be equality only in a carry market. So investors will be indifferent between physical and synthetic commodities in a carry market, and will prefer synthetic commodities at all other times.

SUMMARY

At a general level, commodity forward prices can be described by the same formula as financial forward prices:

$$F_{0,T} = S_0 e^{(r-\delta)T} \qquad (15.15)$$

For financial assets, δ is the dividend yield. For commodities, δ is the commodity *lease rate*—the return that makes an investor willing to buy and then lend a commodity. Thus, for the commodity owner who lends the commodity, it is like a dividend. From the commodity

[11] Index investors have to periodically exchange an expiring futures contract for a new long position. This transaction is referred to as "rolling" the position. For large index investors, the dollar amount of this futures roll can be substantial. Mou (2010) provides evidence that price effects from the roll are predictable and that front-running it can be profitable.

[12] Historical commodity and futures data, necessary to estimate expected commodity returns, and thus to evaluate commodity investing as a strategy, are relatively hard to obtain. Bodie and Rosansky (1980) examine quarterly futures returns from 1950 to 1976, while Gorton and Rouwenhorst (2004) examine monthly futures returns from 1959 to 2004. Both studies construct portfolios of synthetic commodities—T-bills plus commodity futures—and find that these portfolios earn the same average return as stocks, are on average negatively correlated with stocks, and are positively correlated with inflation. These findings imply that a portfolio of stocks and synthetic commodities would have the same expected return and less risk than a diversified stock portfolio alone.

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borrower's perspective, it is the cost of borrowing the commodity.

Different issues arise with commodity forwards than with financial forwards. For both commodities and financial assets, the forward price is the expected spot price discounted at the risk premium on the asset. (As with financial forwards, commodity forward prices are biased predictors of the future spot price when the commodity return contains a risk premium.) Storage of a commodity is an economic decision in which the investor compares the benefit from selling today with the benefit of selling in the future. When commodities are stored, the forward price must be sufficiently high so that a cash-and-carry compensates the investor for both financing and storage costs (this is called a carry market). When commodities are not stored, the forward price reflects the expected future spot price. Forward prices that are too high can be arbitraged with a cash-and-carry, while forward prices that are lower may not be arbitrageable, as the terms of a short sale should be based on the forward price. Some holders of a commodity receive a benefit from physical ownership. This benefit is called the commodity's *convenience yield*, and convenience can lower the forward price,

Forward curves provide information about individual commodities, each of which differs in the details. Forward curves for different commodities reflect different properties of storability, storage costs, production, demand, and seasonality. Electricity, gold, corn, natural gas, and oil all have distinct forward curves, reflecting the different characteristics of their physical markets. These idiosyncracies will be reflected in the individual commodity lease rates.

It is possible to create synthetic commodities by combining commodity futures and default-free bonds. In general it is financially preferable to invest in a synthetic rather than a physical commodity. Synthetic commodity indexes have been popular investments in recent years.

Further Reading

Geman (2005) and Siegel and Siegel (1990) provide a detailed discussion of many commodity futures. There are numerous papers on commodities. Bodie and Rosansky (1980) and Gorton and Rouwenhorst (2004) examine the risk and return of commodities as an investment. Brennan (1991), Pindyck (1993b), and Pindyck (1994) examine the behavior of commodity prices. Schwartz (1997) compares the performance of different models of commodity price behavior. Jarrow and Oldfield (1981) discuss the effect of storage costs on pricing, and Routledge et. al. (2000) present a theoretical model of commodity forward curves. The websites of commodity exchanges are also useful resources, with information about particular contracts and sometimes about trading and hedging strategies.

Finally, Metallgesellschaft engendered a spirited debate. Papers written about that episode include Culp and Miller (1995), Edwards and Canter (1995), and Mello and Parsons (1995).

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Exchanges, OTC Derivatives, DPCs and SPVs

16

Learning Objectives

After completing this reading you should be able to:

- Describe how exchanges can be used to alleviate counterparty risk.
- Explain the developments in clearing that reduce risk.
- Compare exchange-traded and OTC markets and describe their uses.
- Identify the classes of derivative securities and explain the risk associated with them.
- Identify risks associated with OTC markets and explain how these risks can be mitigated.

Excerpt is Chapter 2 of Central Counterparties: Mandatory Clearing and Bilateral Margin Requirements for OTC Derivatives, *by Jon Gregory.*

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A too-big-to-fail firm is one whose size, complexity, interconnectedness, and critical functions are such that, should the firm go unexpectedly into liquidation, the rest of the financial system and the economy would face severe adverse consequences.

—Ben Bernanke (1953–)

EXCHANGES

What Is an Exchange?

In derivative markets, many contracts are exchange-traded. An exchange is a central financial centre where parties can trade standardised contracts such as futures and options at a specified price. An exchange promotes market efficiency and enhances liquidity by centralising trading in a single place. The process by which a financial contract becomes exchange-traded can be thought of as a long journey where a critical trading volume, standardisation and liquidity must first develop.

Exchanges have been used to trade financial products for many years. The origins of central counterparties (CCPs) date back to futures exchanges, which can be traced back to the 19th century (and even further). A future is an agreement by two parties to buy or sell a specified quantity of an asset at some time in the future at a price agreed upon today. Futures were developed to allow merchants or companies to fix prices for certain assets, and therefore be able to hedge their exposure to price movements. An exchange was essentially a market where standardised contracts such as futures could be traded. Originally, exchanges were simply trading forums without any settlement or counterparty risk management functions. Transactions were still done on a bilateral basis and trading through the exchange simply provided a certification through the counterparty being a member of the exchange. Members not fulfilling their requirements were deemed in default and were fined or expelled from the exchange.

An exchange performs a number of functions:

- *Product standardisation*: An exchange designs contracts that can be traded where most of the terms (e.g., maturity dates, minimum price quotation increments, deliverable grade of the underlying, delivery location and mechanism) are standardised.
- *Trading venue*: Exchanges provide either a physical or an electronic trading facility for the underlying products they list, which provides a central venue for trading and hedging. Access to an exchange is limited to approved firms and individuals who must abide by the rules of the exchange. This centralised trading venue provides an opportunity for price discovery.[1]
- *Reporting services*: Exchanges provide various reporting services of transaction prices to trading participants, data vendors and subscribers. This creates a greater transparency of prices.

The Need for Clearing

In addition to their functions as described above, exchanges have also provided methods for improving 'clearing' and therefore mitigating counterparty risk. Clearing is the term that describes the reconciling and resolving of contracts between counterparties, and takes place between trade execution and trade settlement (when all legal obligations have been made). A buyer or seller suffering a large loss on a contract may be unable or unwilling to settle the underlying position and two methods have developed for reducing this risk, namely margining and netting.

Margining involves exchange members receiving and paying cash or other assets against gains and losses in their positions (variation margin) and providing extra coverage against losses in case they default (initial margin). Exchange rules developed to specify and enforce the mechanics of margin exchange.

Netting involves the offsetting of contracts, which is useful to reduce the exposure of counterparties and the underlying network to which they are exposed. It therefore reduces the costs of maintaining open positions such as via the margins needing to be posted. Historically, netting can be seen in all of the three forms of clearing that have developed, namely direct clearing, ring clearing and complete clearing, which are described next.

Direct Clearing

Direct clearing refers to a bilateral reconciliation of commitments between the original two counterparties (which

[1] This is the process of determining the price of an asset in a marketplace through the interactions of buyers and sellers.

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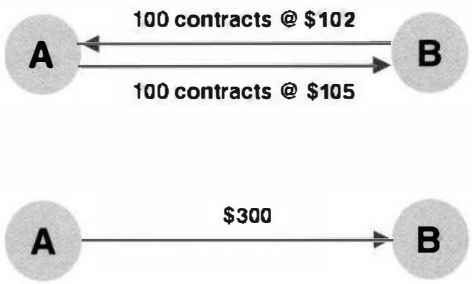

FIGURE 16-1 Illustration of direct clearing.

is obviously the standard clearing mechanism if no other is specified). Here, the specified terms of a transaction may be performed directly, e.g., one counterparty may deliver the underlying contractual amount of an asset to the other in exchange for the pre-specified payment in cash. Alternatively, if the counterparties have offsetting trades then they can reduce obligations as illustrated in Figure 16-1. Here, counterparties A and B have offsetting positions with each other in the same contracts: A has an agreement to buy 100 contracts from B at a price of $105 at a later date, whilst B has the exact reverse position with A but at a lower price of $102. Clearly, standardisation of terms facilitates such offset by making contracts fungible. Rather than A and B physically exchanging 100 contracts worth of the underlying and making associated payments of $10,500 and $10,200 to one another they can use 'payment of difference'. Payment of difference, rather than delivery, became common in futures markets to reduce problems associated with creditworthiness. In Figure 16-1, this would involve counterparty A paying counterparty B the difference in the value of the contracts of $300. This could occur at the settlement date of the contract or at any time before. In the OTC derivatives market, this form of direct clearing is now generally called netting.

Obviously, in direct clearing original counterparties still have exposure to one another, albeit potentially reduced by methods such as payment of differences. Although exchanges facilitate such approaches by, for example, defining standard contractual terms, they have limited additional roles to play in such a structure, potentially just as mediators in any ensuing dispute.

Clearing Rings

The fungibility created by standardisation means that direct clearing can be extended to more than two counterparties. Historically, the development of 'clearing rings' was a means of utilising standardisation to ease aspects such as closing out positions and enhancing liquidity. For instance, prior to the adoption of 'complete clearing' at the Chicago Board of Trade, groups of three or more market participants would 'ring out' offsetting positions. Clearing rings were relatively informal means of reducing exposure via a ring of three or more members. To achieve the benefits of 'ringing', participants in the ring had to be willing to accept substitutes for their original counterparties. Rings were voluntary but once joining a ring, exchange rules bound participants to the ensuing settlements. Some members would choose not to join a ring whereas others might participate in multiple rings. In a clearing ring, groups of exchange members agree to accept each other's contracts and allow counterparties to be interchanged. This can be useful for reducing bilateral exposure as illustrated in Figure 16-2. Irrespective of the nature of the other positions, the positions between C and D, and D and B can allow a 'ringing out' where D is removed from the ring and two obligations are replaced with a single one from C to B.

Clearing rings clearly reduce counterparty risk. They also simplify the dependencies of a member's open positions and allow them to close out contracts more easily,

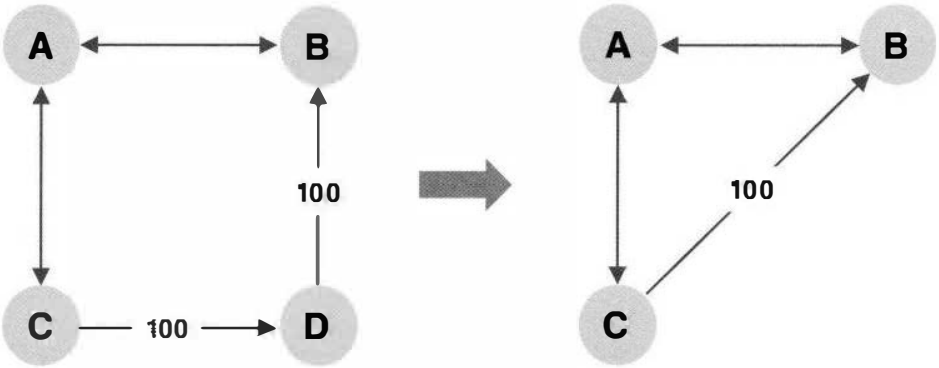

FIGURE 16-2 Illustration of a clearing ring. The equivalent obligations between C and D and between D and B are replaced with a single obligation between C and B.

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increasing liquidity. Clearly, all members of the ring must agree a price for settling contracts, which may be facilitated by the exchange. Historically, exchanges (and courts) have generally upheld the contractual features of ringing. For example, if (via a ring) a counterparty had their original counterparty replaced via another that subsequently defaulted, then they could not challenge the clearing ring reassignment that led to this.

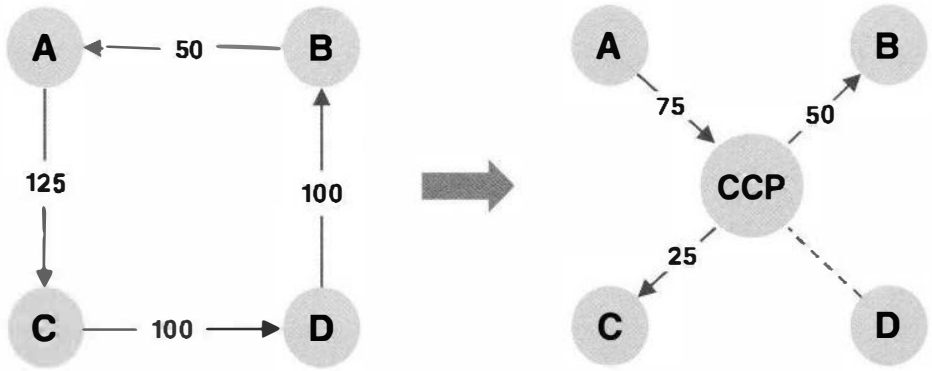

FIGURE 16-3 Illustration of complete clearing. The CCP assumes all contractual responsibilities as counterparty to all contracts.

It is important to note that not all counterparties in the example shown in Figure 16-2 benefit from the clearing ring illustrated (although of course there may be other clearing simplifications not shown that may benefit them). Whilst D clearly benefits from being able to offset readily the transactions with C and B, A is indifferent to the formation of the ring since its positions are not changed. Furthermore, the positions of B and C have changed only in terms of the replacement counterparty they have been given. Clearly, if this counterparty is considered to have stronger (weaker) credit quality then they view the ring as a benefit (detriment). A ring, whilst offering a collective benefit, is unlikely to be seen as beneficial by all participants. A member at the 'end of a ring' with only a long or short position and therefore standing not to benefit has no benefit to ring out. Historically, such aspects have played out with members refusing to participate in rings because, for example, they preferred larger exposures to certain counter-parties rather than smaller exposures to other counter-parties.

In the current OTC derivative market, compression offers a similar mechanism to the historical role of clearing rings.

Complete Clearing

Clearing rings reduce but do not completely eliminate the counterparty-specific nature of contracts and the resulting risk in the event of counterparty failure. Members are still exposed to the failure of their counterparties. Furthermore, like dominoes, contract failures can create a cascading effect and lead a string of seemingly unrelated counterparties to fail. A good historical example of this is the 1902 bankruptcy of George Phillips, which affected hundreds of clearing members of the Chicago Board of Trade representing almost half of the total membership. To remedy such problems, the final stage in the development of clearing is complete clearing where a CCP or 'clearinghouse' becomes counterparty to all transactions.

When trading a derivative, the counterparties agree to fulfil specific obligations to each other. By interposing itself between two counter-parties,[2] which are clearing members, a CCP assumes all such contractual rights and responsibilities as illustrated in Figure 16-3. This facilitates the offsetting of transactions as in clearing rings but also reduces counterparty risk further, as a member no longer needs to be concerned about the credit quality of its counterparty. Indeed, the counterparty to all intents and purposes is the CCP.

Complete clearing originated in Europe and was adopted in the US by the end of the 19th century (although full novation of contracts did not occur until the early 20th century). Following the development of central clearing, as new futures exchanges were established, central counterparty clearing was often the chosen structure from the start.

Faced with counterparty risk, CCPs adopted rules to limit their exposures. In addition to the offset that this clearing structure facilitated, they used already developed margining rules to protect themselves from the risk of insolvency of one of their members. Margin generally evolved to be

[2] Sometimes CCPs do not interpose themselves but rather guarantee the performance of the trade. This has historically been the case in US markets compared to Europe. Nevertheless, the end result is similar.

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dynamic using daily mark-to-market valuation to define *variation margin* relating to daily payment of profits and losses, as well as *initial margin* to cover the potential close out cost of positions that a CCP could experience when a member defaulted. Additional to margin requirements, CCPs developed a loss sharing model. All clearing members had to make share purchases, which entitled them to use the exchange. In the event of a clearing member failure, the clearing members were at risk of losing their equity investment (but not more). This equity is the basis of what CCPs define as default funds today.

Adoption of central clearing has not been completely without resistance: the Chicago Board of Trade (CBOT) did not have a CCP function for around 30 years until 1925 (and then partly as a result of government pressure). One of the last futures exchanges to adopt a CCP was the London Metal Exchange in 1986 (again with regulatory pressure being a key factor). An obvious and often cited reason for these resistances is the fact that clearing homogenises counterparty risk and therefore would lead to strong credit quality members of the exchange suffering under central clearing compared to the weaker members. The reluctance to adopt clearing voluntarily certainly raises the possibility that the costs of clearing exceed the benefits, at least in some markets.

Nevertheless, all exchange-traded contracts are currently subject to central clearing. The CCP function may either be operated by the exchange or provided to the exchange as a service by an independent company. All derivatives exchanges have adopted some form of a CCP and central counterparty clearing was therefore the standard practice for derivatives markets clearing until the arrival of the OTC derivatives market in the last quarter of the 20th century.

OTC DERIVATIVES

OTC vs. Exchange-Traded

Exchange-traded derivatives are standardised contracts (e.g., futures and options) and are actively traded in the secondary markets. It is easy to buy a contract and sell the equivalent contract to close the position, which can be done via one or more derivative exchanges. Prices are transparent and accessible to a wide range of market participants.

OTC markets work very differently compared to exchange-traded ones, as outlined in Table 16-1. OTC derivatives are traditionally privately negotiated and traded directly between two parties without an exchange or other intermediary involved. Prices are not firm commitments to trade and price negotiation is purely a bilateral process. OTC derivatives have traditionally been negotiated between a dealer and end user or between two dealers. OTC markets did not historically include trade reporting, which is difficult because trades can occur in private, without activity being visible on any exchange. Documentation is also bilaterally negotiated between the two parties, although certain standards have been developed. In bilateral OTC markets, each party takes counterparty risk to the other and must manage it themselves.

TABLE 16-1 Comparison Between Exchange-Traded and OTC Derivatives

	Exchange-Traded	Over-the-Counter (OTC)
Terms of contract Maturity	• Standardised (maturity, size, strike, etc.) • Standard maturities, typically at most a few months	• Flexible and negotiable • Negotiable and non-standard • Often many years
Liquidity	• Very good	• Limited and sometimes very poor for non-standard or complex products
Credit risk	• Guaranteed by CCP	• Bilateral

The most important factor influencing the popularity of OTC products is the ability to tailor contracts more precisely to client needs, for example by offering a particular maturity date. Exchange-traded products by their nature do not offer customisation. Key players in the OTC market are banks and other highly sophisticated parties, such as hedge funds. Interdealer brokers also play a role in intermediating OTC derivatives transactions. Prior to 2007, whilst the OTC market was the largest market for derivatives, it was largely unregulated.

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It is important not to confuse customised with exotic OTC derivatives. For example, a customer wanting to hedge their production or use of an underlying asset at specific dates may do so through a customised OTC derivative. Such a hedge may not be available on an exchange, where the underlying contracts will only allow certain standard contractual terms (e.g., maturity dates) to be used. A customised OTC derivative may be considered more useful for risk management than an exchange-traded derivative, which would give rise to additional 'basis risk' (in this example, the mismatch of maturity dates). It has been reported that the majority of the largest companies in the world use derivatives in order to manage their financial risks.[3] Due to the idiosyncratic hedging needs of such companies, OTC derivatives are commonly used instead of their exchange-traded equivalents.

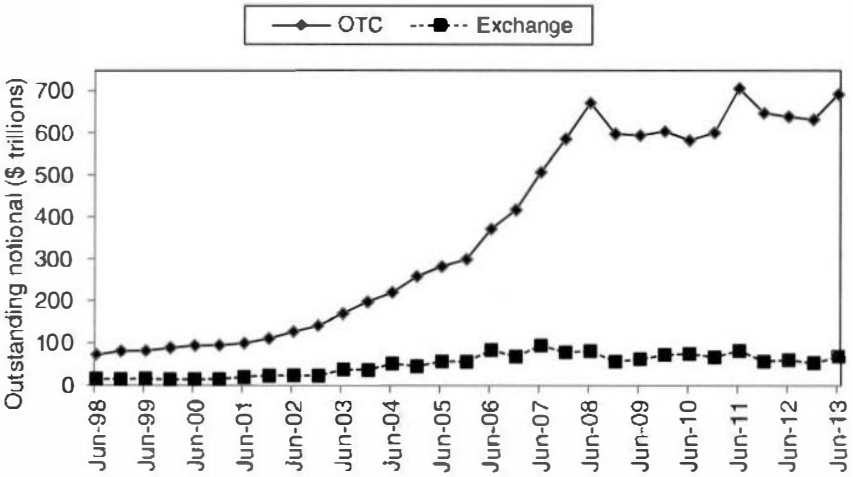

FIGURE 16-4 Total outstanding notional of OTC and exchange-traded derivatives transactions. The figures cover interest rate, foreign exchange, equity, commodity and credit derivative contracts. Note that notional amounts outstanding are not directly comparable to those for exchange-traded derivatives, which refer to open interest or net positions whereas the amounts outstanding for OTC markets refer to gross positions, i.e. without netting. Centrally cleared trades also increase the total notional outstanding due to a double counting effect since clearing involves book two separate transactions.

Source: BIS.

Customised OTC derivatives are not without their disadvantages, of course. A customer wanting to unwind a transaction must do it with the original counterparty, who may quote unfavourable terms due to their privileged position. Even assigning or novating the transaction to another counterparty typically cannot be done without the permission of the original counterparty. This lack of fungibility in OTC transactions can also be problematic. This aside, there is nothing wrong with customising derivatives to the precise needs of clients as long as this is the sole intention. However, this is not the only use of OTC derivatives: some are contracted for regulatory arbitrage or even (arguably) misleading a client. Such products are clearly not socially useful and generally fall into the (relatively small) category of exotic OTC derivatives which in turn generate much of the criticism of OTC derivatives in general.

OTC derivatives markets remained relatively small until the 1980s, in part due to regulation, and also due to the benefits in terms of liquidity and counterparty risk control for exchange-traded derivatives. However, from that point on, advances in financial engineering and technology together with favourable regulation led to the rapid growth of OTC derivatives as illustrated in Figure 16-4. The strong expansion of OTC derivatives against exchange-traded derivatives is also partly due to exotic contracts and new markets such as credit derivatives (the credit default swap market increased by a factor of 10 between the end of 2003 and end of 2008). OTC derivatives have in recent years dominated their exchange-traded equivalents in notional value[4] by something close to an order to magnitude.

Another important aspect of OTC derivatives is their concentration with respect to a relatively small number of commercial banks, often referred to as 'dealers'. For example, in the US, four large commercial banks represent

[3] Over 94% of the World's Largest Companies Use Derivatives to Help Manage Their Risks, According to ISDA Survey", ISDA Press Release, 23 April 2009, http://www.isda.org/press/press042309der.pdf.

[4] Not by number of transactions, as OTC derivatives trades tend to be much larger.

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90% of the total OTC derivative notional amounts.[5]

Market Development

The total notional amount of all derivatives outstanding was $761 trillion in mid-2013. The curtailed growth towards the end of the history in Figure 16-4 can be clearly attributed to the global financial crisis (GFC), where finns have reduced balance sheets and reallocated capital, and clients have been less interested in derivatives, particularly as structured products. However, the reduction in recent years is also partially due to compression exercises that seek to reduce counterparty risk by removing offsetting and redundant positions (discussed in more detail in the next chapter).

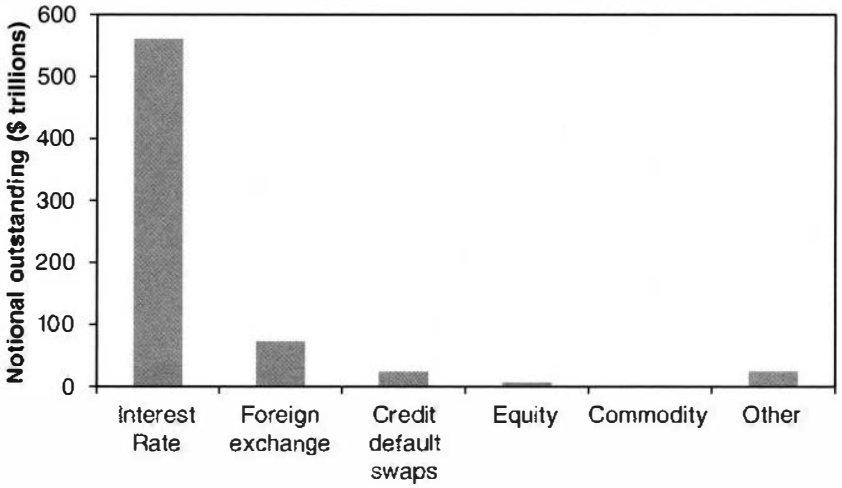

FIGURE 16-5 Split of OTC derivative gross outstanding notional by product type as of June 2013. Note that centrally cleared products are double counted since a single trade is novated into two trades in a CCP. This is particularly relevant for interest rate products, for which a large outstanding notional is already centrally cleared.

Source: BIS.

OTC derivatives include the following five broad classes of derivative securities: interest rate derivatives, foreign exchange derivatives, equity derivatives, commodity derivatives and credit derivatives. The split of OTC derivatives by product type is shown in Figure 16-5. Interest rate products contribute the majority of the outstanding notional, with foreign exchange and credit default swaps seemingly less important. However, this gives a somewhat misleading view of the importance of counterparty risk in other asset classes, especially foreign exchange and credit default swaps. Whilst most foreign exchange products are short-dated, the long-dated nature and exchange of notional in cross-currency swaps means they carry a lot of counterparty risk. Credit default swaps not only have a large volatility component but also constitute significant 'wrong-way risk'. Therefore, whilst interest rate products make up a significant proportion of the counterparty risk in the market, one must not underestimate the other important (and sometimes more subtle) contributions from other products.

A key aspect of derivatives products is that their exposure is substantially smaller than that of an equivalent loan or bond. Consider an interest rate swap as an example: this contract involves the exchange of floating against fixed coupons and has no principal risk because only cashflows are exchanged. Furthermore, even the coupons are not fully at risk because, at coupon dates, only the difference in fixed and floating coupons or *net* payment will be exchanged. If a counterparty fails to perform then an institution will have no obligation to continue to make coupon payments. Instead, the swap will be unwound based on (for example) independent quotations as to its current market value. If the swap has a negative value for an institution then they may stand to lose nothing if their counterparty defaults.[6] For this reason, when we compare the actual total market of derivatives against their total notional amount outstanding, we see a massive reduction as illustrated in Table 16-2. For example, the total market value of interest rate contracts is only 2.7% of the total notional outstanding.

Derivatives contracts have, in many cases, become more standardised over the years through industry initiatives. This standardisation has come about as a result of a

[5] Officer of the Comptroller of the Currency, 'OCC's Quarterly Report on Bank Trading and Derivatives Activities First Quarter 2013'. Table 3, http://www.occ.gov/topics/capital-markets/financial-markets/trading/derivatives/dqtl3.pdf.

[6] Assuming the swap can be replaced without any additional cost.

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TABLE 16-2 Comparison of the Total Notional Outstanding and the Market Value of OTC Derivatives (in $ trillions) for Different Asset Classes as of June 2013

	Gross Notional Outstanding	Gross Market Value*	Ratio
Interest rate	561.3	15.2	2.7%
Foreign exchange	73.1	2.4	3.3%
Credit default swaps	24.3	0.7	3.0%
Equity	6.8	0.7	10.2%
Commodity	2.4	0.4	15.7%

* This is calculated as the sum of the absolute value of gross positive and gross negative market values, corrected for double counting.

Source: BIS.

natural lifecycle where a product moves gradually from non-standard and complex to becoming more standard and potentially less exotic. Nevertheless, OTC derivative markets remain decentralised and more heterogeneous, and are consequently less transparent than their exchange-traded equivalents. This leads to potentially challenging counterparty risk problems. OTC derivatives markets have historically managed this counterparty risk through the use of netting agreements, margin requirements, periodic cash resettlement, and other forms of bilateral credit mitigation.

OTC Derivatives and Clearing

An OTC derivatives contract obliges its counterparties to make certain payments over the life of the contract (or until an early termination of the contract). 'Clearing' is the process by which payment obligations between two or more finns are computed (and often netted), and 'settlement' is the process by which those obligations are effected. The means by which payments on OTC derivatives are cleared and settled affect how the credit risk borne by counterparties in the transaction is managed. A key feature of many OTC derivatives is that they are not settled for a long time since they generally have long maturities. This is in contrast to exchange-traded products, which often settle in days or, at the most, months. Clearing is therefore more important and difficult for OTC derivatives.

OTC and exchange-traded derivatives generally have two distinct mechanisms for clearing and settlement: bilateral for OTC derivatives and central for exchange-traded structures. Risk-management practices, such as margining, are dealt with bilaterally by the counterparties to each OTC contract, whereas for exchange-traded derivatives the risk management functions are typically carried out by the associated CCP. However, an OTC derivative does not have to become exchange-traded to benefit from central clearing. CCPs have for many years operated as separate entities to control counterparty risk by mutualising it amongst the CCP members. Prior to any clearing mandate, almost half the (OTC) interest-rate swap market was centrally cleared by LCH.Clearnet's SwapClear service (although almost all other OTC derivatives were still bilaterally traded).

An important aspect for CCPs is the heterogeneity of the OTC market, since clearing requires a degree of homogeneity between its members. Historically, the large OTC derivatives players have had much stronger credit quality than the other participants. However, some small players such as sovereigns and insurance companies have had very strong (triple-A) credit quality, and have used this to obtain favourable terms such as one-way margin agreements.

Banks have historically dealt with counterparty risk in a variety of ways. For instance, a bank may not require a counterparty to post any margin at the initiation of a transaction as long as the amount it owes remains below a pre-established credit limit. Counterparty risk is now commonly priced into transactions via credit value adjustment (CVA). Before we discuss central clearing in more detail in the next chapter, it is useful to first review some of the other counterparty risk reduction methods used in the OTC market prior to 2007.

COUNTERPARTY RISK MITIGATION IN OTC MARKETS

Systemic Risk

A major concern with respect to OTC derivatives is systemic risk. A major systemic risk episode would likely involve an initial spark followed by a proceeding chain reaction, potentially leading to some sort of explosion in financial markets. Thus, in order to control systemic risk,

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one can either minimise the chance of the initial spark, attempt to ensure that the chain reaction does not occur, or simply plan that the explosion is controlled and the resulting damage limited.

Historically, most OTC risk mitigants focused on reducing the possibility of the initial spark mentioned above. Reducing the default risk of large, important market participants is an obvious route. Capital requirements, regulation and prudential supervision can contribute to this but there is a balance between reduction of default risk and encouraging financial firms to grow and prosper.

OTC derivatives markets have netting, margining and other methods to minimise counterparty and systemic risk. However, such aspects create more complexity and may catalyse growth to a level that would never have otherwise been possible. Hence it can be argued that initiatives to stifle a chain reaction may achieve precisely the opposite and create the catalyst (such as many large exposures supported by a complex web of margining) to cause the explosion.

The OTC derivative market also developed other mechanisms for potentially controlling the inherent counterparty and systemic risks they create. Examples of these mechanisms are SPVs, DPCs, monolines and CDPCs, which are discussed next. Although these methods have been largely deemed irrelevant in today's market, they share some common features with CCPs and a historical overview of their development is therefore useful.

However, without the correct management and regulation, ultimately even seemingly strong financial institutions can collapse. The ultimate solution to systemic risk may therefore be simply to have the means in place to manage periodic failures in a controlled manner, which is one role of a CCP. If there is a default of a key market participant, then the CCP will guarantee all the contracts that this counterparty has executed through them as a clearing member. This will mitigate concerns faced by institutions and prevent any extreme actions by those institutions that could worsen the crisis. Any unexpected losses caused by the failure of one or more counterparties would be shared amongst all members of the CCP (just as insurance losses are essentially shared by all policyholders) rather than being concentrated within a smaller number of institutions that may be heavily exposed to the failing counterparty. This 'loss mutualisation' is a key component as it mitigates systemic risk and prevents a domino effect.

Special Purpose Vehicles

A Special Purpose Vehicle (SPV) or Special Purpose Entity (SPE) is a legal entity (e.g., a company or limited partnership) created typically to isolate a firm from financial risk. SPVs have been used in the OTC derivatives market to protect from counterparty risk. A company will transfer assets to the SPV for management or use the SPV to finance a large project without putting the entire firm or a counterparty at risk. Jurisdictions may require that an SPV is not owned by the entity on whose behalf it is being set up.

SPVs aim essentially to change bankruptcy rules so that, if a derivative counterparty is insolvent, a client can still receive their full investment prior to any other claims being paid out. SPVs are most commonly used in structured notes, where they use this mechanism to guarantee the counterparty risk on the principal of the note to a very high level (triple-A typically), better than that of the issuer. The creditworthiness of the SPV is assessed by rating agencies who look in detail at the mechanics and legal specifics before granting a rating.

SPVs aim to shift priorities so that in a bankruptcy, certain parties can receive a favourable treatment. Clearly, such a favourable treatment can only be achieved by imposing a less favourable environment on other parties. More generally, such a mechanism may then reduce risk in one area but increase it in another. CCPs also create a similar shift in priorities, which may move, rather than reduce, systemic risk.

An SPV transforms counterparty risk into legal risk. The obvious legal risk is that of *consolidation*, which is the power of a bankruptcy court to combine the SPV assets with those of the originator. The basis of consolidation is that the SPV is essentially the same as the originator and means that the isolation of the SPV becomes irrelevant. Consolidation may depend on many aspects such as jurisdictions. US courts have a history of consolidation rulings, whereas UK courts have been less keen to do so, except in extreme cases such as fraud.

Another lesson is that legal documentation often evolves through experience, and the enforceability of the legal structure of SPVs was not tested for many years. When it was tested in the case of Lehman Brothers, there were problems (although this depended on jurisdiction). Lehman essentially used SPVs to shield investors in complex transactions such as Collateralised Debt Obligations

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(CDOs) from Lehman's own counterparty risk (in retrospect a great idea). The key provision in the documents is referred to as the 'flip' provision, which essentially meant that if Lehman were bankrupt then the investors would be first in line as creditors. However, the US Bankruptcy Court ruled the flip clauses were unenforceable, putting them at loggerheads with the UK courts, which ruled that the flip clauses were enforceable. Just to add to the jurisdiction-specific question of whether a flip clause and therefore an SPV was a sound legal structure, many cases have been settled out of court.[7] Risk mitigation that relies on very sound legal foundations may fail dramatically if any of these foundations prove to be unstable. This is also a potential lesson for CCPs, who must be certain of their legal authorities in a situation such as a default of one of their members.

Derivatives Product Companies

Long before the GFC of 2007 onwards, whilst no major derivatives dealer had failed, the bilaterally cleared dealer-dominated OTC market was perceived as being inherently more vulnerable to counterparty risk than the exchange-traded market. The derivatives product company (or corporation) evolved as a means for OTC derivative markets to mitigate counterparty risk (e.g., see Kroszner 1999). DPCs are generally triple-A rated entities set up by one or more banks as a bankruptcy-remote subsidiary of a major dealer, which, unlike an SPV, is separately capitalised to obtain a triple-A credit rating.[8] The DPC structure provides external counterparties with a degree of protection against counterparty risk by protecting against the failure of the DPC parent. A DPC therefore provided some of the benefits of the exchange-based system while preserving the flexibility and decentralisation of the OTC market. Examples of some of the first DPCs include Merrill Lynch Derivative Products, Salomon Swapco, Morgan Stanley Derivative Products and Lehman Brothers Financial Products.

The ability of a sponsor to create their own 'mini derivatives exchange' via a DPC was partially a result of improvements in risk management models and the development of credit rating agencies. DPCs maintained a triple-A rating by a combination of capital, margin and activity restrictions. Each DPC had its own quantitative risk assessment model to quantify their current credit risk. This was benchmarked against that required for a triple-A rating. Most DPCs use a dynamic capital allocation to keep within the triple-A credit risk requirements. The triple-A rating of a DPC typically depends on:

- *Minimising market risk*: In terms of market risk, DPCs can attempt to be close to market-neutral via trading offsetting contracts. Ideally, they would be on both sides of every trade as these 'mirror trades' lead to an overall matched book. Normally the mirror trade exists with the DPC parent.
- *Support from a parent*: The DPC is supported by a parent with the DPC being bankruptcy-remote (like an SPV) with respect to the parent to achieve a better rating. If the parent were to default, then the DPC would either pass to another well-capitalised institution or be terminated, with trades settled at mid-market.
- *Credit risk management and operational guidelines (limits, margin terms, etc.):* Restrictions are also imposed on (external) counter-party credit quality and activities (position limits, margin, etc.). The management of counterparty risk is achieved by having daily mark-to-market and margin posting.

Whilst being of very good credit quality, DPCs also aimed to give further security by defining an orderly workout process. A DPC defined what events would trigger its own failure (rating downgrade of parent, for example) and how the resulting workout process would work. The resulting 'pre-packaged bankruptcy' was therefore supposedly simpler (as well as less likely) than the standard bankruptcy of an OTC derivative counterparty. Broadly speaking, two bankruptcy approaches existed, namely a continuation and termination structure. In either case, a manager was responsible for managing and hedging existing positions (continuation structure) or terminating transactions (termination structure).

There was nothing apparently wrong with the DPC idea, which worked well since its creation in the early 1990s. DPCs were created in the early stages of the OTC derivative market to facilitate trading of long-dated derivatives by counterparties having less than triple-A credit quality. However, was such a triple-A entity of a double-A or worse bank really a better counterparty than the bank itself? In the early years, DPCs experienced steady growth

[7] For example, see 'Lehman opts to settle over Dante flip-clause transactions' http://www.risk.net/risk-magazine/news/1899105/lehman-opts-settle-dante-flip-clause-transactions.

[8] Most DPCs derived their credit quality structurally via capital, but some simply did so more trivially from the sponsors' rating.

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in notional volumes, with business peaking in the mid-to-late 1990s. However, the increased use of margin in the market, and the existence of alternative triple-A entities led to a lessening demand for DPCs.

The GFC essentially killed the already declining world of DPCs. After their parent's decline and rescue, the Bear Steams DPCs were wound down by J.P. Morgan, with clients compensated for novating trades. The voluntary filing for Chapter 11 bankruptcy protection by two Lehman Brothers DPCs, a strategic effort to protect the DPCs' assets, seems to link a DPC's fate inextricably with that of its parent. Not surprisingly, the perceived lack of autonomy of DPCs has led to a reaction from rating agencies, who have withdrawn ratings.[9]

Whilst DPCs have not been responsible for any catastrophic events, they have become largely irrelevant. As in the case of SPVs, it is clear that the DPC concept is a flawed one. The perceived triple-A ratings of DPCs had little credibility as the counterparty being faced was really the DPC parent, generally with a worse credit rating. Therefore, DPCs again illustrate that a conversion of counterparty risk into other financial risks (in this case not only legal risk as in the case of SPVs but also market and operational risks) may be ineffective.

Monolines and CDPCs

As described above, the creation of DPCs was largely driven by the need for high-quality counterparties when trading OTC derivatives. However, this need was taken to another level by the birth and exponential growth of the credit derivatives market from around 1998 onwards. The first credit derivative product was the single name credit default swap (CDS). The CDS represents an unusual challenge since its mark-to-market is driven by credit spread changes whilst its payoff is linked solely to one or more credit events (e.g. default). The so-called wrong-way risk in CDS (for example, when buying protection on a bank from another bank) meant that the credit quality of the counterparty became even more important than it would be for other OTC derivatives. Beyond single name credit default swaps, senior tranches of structured finance CDOs had even more wrong-way risk and created an even stronger need for a 'default remote entity'.

Monoline insurance companies (and similar companies such as AIG)[10] were financial guarantee companies with strong credit ratings that they utilised to provide 'credit wraps' which are financial guarantees. Monolines began providing credit wraps for other areas but then entered the single name CDS and structured finance arena to achieve diversification and better returns. Credit derivative product companies (CDPCs) were an extension of the DPC concept discussed in the last section that had business models similar to those of monolines.

In order to achieve good ratings (e.g., triple-A), monolines/CDPCs had capital requirements driven by the possible losses on the structures they provide protection on. Capital requirements were also dynamically related to the portfolio of assets they wrapped, which is similar to the workings of the DPC structure. Monolines and CDPCs typically did not have to post margin (at least in normal times) against a decline in the mark-to-market value of their contracts (due to their excellent credit rating).

From November 2007 onwards, a number of monolines (for example, XL Financial Assurance Ltd, AMBAC Insurance Corporation and MBIA Insurance Corporation) essentially failed. In 2008, AIG was bailed out by the US government to the tune of approximately US$182 billion (the reason why AIG was bailed out and the monoline insurers were not was the size of AIG's exposures[11] and the timing of their problems close to the Lehman Brothers bankruptcy). These failures were due to a subtle combination of rating downgrades, required margin postings and mark-to-market losses leading to a downwards spiral. Many banks found themselves heavily exposed to monolines due to the massive increase in the value of the protection they had purchased. For example, as of June 2008, UBS was estimated to have US$6.4 billion at risk to monoline insurers whilst the equivalent figures for Citigroup and Merrill Lynch were US$4.8 billion and US$3 billion respectively.[12]

CDPCs, like monolines, were highly leveraged and typically did not post margin. They fared somewhat better

[9] For example, see 'Fitch withdraws Citi Swapco's ratings' http://www.businesswire.com/news/home/20110610005841/en/Fitch-Withdraws-Citi-Swapcos-Ratings.

[10] For the purposes of this analysis, we will categorise monoline insurers and AIG as the same type of entity, which, based on their activities in the credit derivatives market, is fair.

[11] Whilst the monolines together had approximately the same amount of credit derivatives exposure as AIG, their failures were at least partially spaced out.

[12] See 'Banks face $10bn monolines charges', Financial Times, 10 June 2008, http://www.ft.com/cms/s/0/8051c0c4-3715-11dd-bc1c-0000779fd2ac.html#axzz2qH4m4ZLD.

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during the GFC but only for timing reasons. Many CDPCs were not fully operational until after the beginning of the GFC in July 2007. They therefore missed at least the first 'wave' of losses suffered by any party selling credit protection (especially super senior).[13] Nevertheless, the fact that the CDPC business model is close to that of monolines has not been ignored. For example, in October 2008, Fitch Ratings withdrew ratings on the five CDPCs that it rated.[14]

Lessons for Central Clearing

The aforementioned concepts of SPVs, DPCs, monolines and CDPCs have all been shown to lead to certain issues. Indeed, it could be argued that as risk mitigation methods they all have fatal flaws, which explains why there is little evidence of them in today's OTC derivative market. It is important to ask to what extent such flaws may also exist within an OTC CCP, which does share certain characteristics of these structures.

Regarding SPVs and DPCs, two obvious questions emerge. The first is whether shifting priorities from one party to another really helps the system as a whole. CCPs will effectively give priority to OTC derivative counterparties and in doing so may reduce the risk in this market. However, this will make other parties (e.g. bondholders) worse off and may therefore increase risks in other markets. Second, a critical reliance on a precise sound legal framework creates exposure to any flaws in such a framework. This is especially important, as in a large bankruptcy there will likely be parties who stand to make significant gains by challenging the priority of payments (as in the aforementioned SPV flip clause cases). Furthermore, the cross-border activities of CCPs also expose them to bankruptcy regimes and regulatory frameworks in multiple regions.

CCPs also share some similarities with monolines and CDPCs as strong credit quality entities set up to take and manage counterparty risk. However, two very important differences must be emphasised. First, CCPs have a 'matched book' and do not take any residual market risk (except when members default). This is a critical difference since monolines and CDPCs had very large, mostly one-way, exposure to credit markets. Second, a related point is that CCPs require variation and initial margin in all situations whereas monolines and CDPCs would essentially post only variation margin and would often only do this in extreme situations (e.g. in the event of their ratings being downgraded). Many monolines and CDPCs posted no margin at all at the inception of trades. Nevertheless, CCPs are similar to these entities in essentially insuring against systemic risk. However, the term 'systemic risk insurance' is a misnomer, as systemic risk cannot be diversified.

Although CCPs structurally do not suffer from the flaws that caused the failure of monoline insurers or bailout of AIG, there are clearly lessons to be learnt with respect to the centralisation of counterparty risk in a single large and potentially too-big-to-fail entity. One specific example is the destabilising relationship created by increases in margin requirements. Monolines and AIG failed due to a significant increase in margin requirements during a crisis period. CCPs could conceivably create the same dynamic with respect to variation and initial margins, which will be discussed later.

Furthermore, it is possibly unhelpful that some commentators have argued that CCPs would have helped prevent the GFC, for example in relation to AIG. It is true that central clearing would have prevented AIG from building up the enormous exposures that it did. However, AIG's trades would not have been eligible for clearing as they were too non-standard and exotic. Additionally, when virtually all financial institutions, credit ratings agencies, regulators and politicians believed that AIG had excellent credit quality and would be unlikely to fail, it is a huge leap of faith to suggest that a CCP would have had a vastly superior insight or intellectual ability to see otherwise.

Clearing in OTC Derivatives Markets

From the late 1990s, several major CCPs began to provide clearing and settlement services for OTC derivatives and other non-exchange-traded products. This was to help market participants reduce counterparty risk and benefit from the fungibility that central clearing creates. These OTC transactions are still negotiated privately and off-exchange but are then novated into a CCP on a post-trade basis.

In 1999, LCH.Clearnet set up two OTC CCPs to clear and settle repurchase agreements (RepoClear) and plain vanilla interest rate swaps (SwapClear). Commercial

[13] The widening in super senior spreads was on a relative basis much greater than credit spreads in general during late 2007.

[14] See, for example, 'Fitch withdraws CDPC ratings'. Business Wire, 2008.

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interest in OTC-cleared derivatives grew substantially in the energy derivatives market following the bankruptcy of Enron in late 2001. InterContinental Exchange (ICE) responded to this demand by offering cleared OTC energy derivatives solutions beginning in 2002. ICE now offers OTC clearing for credit default swaps (CDSs) also.

Although CCP clearing and settlement of OTC derivatives did develop in the years prior to the GFC, this has been confined to certain products and markets. This suggests that there are both positives and negatives associated with using CCPs and, in some market situations, the positives may not outweigh the negatives. The distinction between securities and OTC clearing is important, with the latter being far less straightforward. For this reason, the major focus of this book is OTC CCPs.

SUMMARY

Most CCPs were originally created by the members of futures exchanges to manage default risk more efficiently and were not designed specifically for OTC derivatives. It is useful to understand the historical development of central clearing and compare it to other forms of counterparty risk mitigation used in derivatives markets such as SPVs, DPCs and monolines. This can provide a good basis for understanding some of the consequences that central clearing will have in the future and some of the associated risks that may be created.

The next chapter will explain the operation of a CCP in more detail.

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Basic Principles of Central Clearing

17

Learning Objectives

After completing this reading you should be able to:

- Provide examples of the mechanics of a central counterparty (CCP).
- Describe advantages and disadvantages of central clearing of OTC derivatives.
- Compare margin requirements in centrally cleared and bilateral markets, and explain how margin can mitigate risk.
- Compare and contrast bilateral markets to the use of novation and netting.
- Assess the impact of central clearing on the broader financial markets.

Excerpt is Chapter 3 of Central Counterparties: Mandatory Clearing and Bilateral Margin Requirements for OTC Derivatives, *by Jon Gregory.*

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[CCPs] emerged gradually and slowly as a result of experience and experimentation.

—Randall Kroszner (1962–)

WHAT IS CLEARING?

Broadly speaking, clearing represents the period between execution and settlement of a transaction, as illustrated in Figure 17-1. At trade execution, parties agree to legal obligations in relation to buying or selling certain underlying securities or exchanging cashflows in reference to underlying market variables. Settlement refers to the completion of all such legal obligations and can occur when all payments have been successfully made or alternatively when the contract is closed out (e.g., offset against another position). Clearing refers to the process between execution and settlement, which in the case of classically cleared products is often a few days (e.g. a spot equity transaction) or at most a few months (e.g. futures or options contracts). For OTC derivatives, the time horizon for the clearing process is more commonly years and often even decades. This is one reason why OTC clearing has such importance in the future as more OTC products become subject to central clearing.

Broadly speaking, clearing can be either bilateral or central. In the former case, the two parties entering a trade take responsibility (potentially with the help of third parties) for the processes during clearing. In the latter case, this responsibility is taken over by a third party such as a central counterparty (CCP).

FUNCTIONS OF A CCP

It is important to emphasise that in the central clearing of non-OTC trades (e.g., securities transactions), the primary role of the CCP is to standardise and simplify operational processes. In contrast, OTC CCPs have a much more significant role to play in terms of counterparty risk mitigation due to the longer maturities and relative illiquidity of OTC derivatives. Much of the discussion below will be focused on OTC clearing.

Financial Markets Topology

A CCP represents a set of rules and operational arrangements that are designed to allocate, manage and reduce counterparty risk in a bilateral market. A CCP changes the topology of financial markets by inter-disposing itself between buyers and sellers as illustrated in Figure 17-2. In this context, it is useful to consider the six entities denoted by D, representing large global banks often known as 'dealers'. Two obvious advantages appear to stem from this simplistic view. First, a CCP can reduce the *interconnectedness* within financial markets, which may lessen the impact of an insolvency of a participant. Second, the CCP being at the heart of trading can provide more *transparency* on the positions of the members. An obvious problem here is that a CCP represents the centre of a 'hub and spoke' system and consequently its failure would be a catastrophic event.

OTC CCPs will change dramatically the topology of the global financial system. The above analysis is clearly rather simplistic and although the general points made are correct, the true CCP landscape is much more complex than represented above.

Novation

A key concept in central clearing is that of contract novation, which is the legal process whereby the CCP is positioned between buyers and sellers. Novation is the replacement of one contract with one or more other contracts. Novation means that the CCP essentially steps in between parties to a transaction and therefore acts as an insurer of counterparty risk in both directions. The viability of novation depends on the legal enforceability of the new contracts and the certainty that the original parties are not legally obligated to each other once the novation is completed. Assuming this viability, novation means that the contract

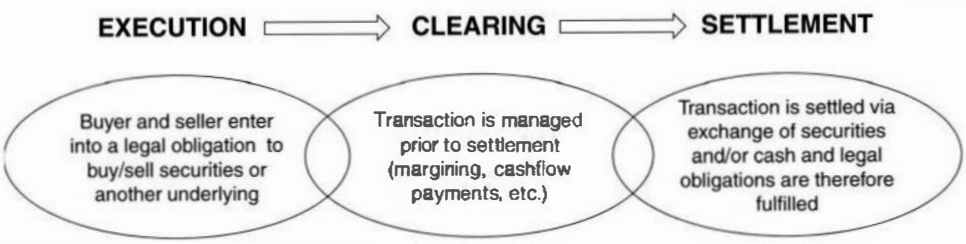

FIGURE 17-1 Illustration of the role of clearing in financial transactions.

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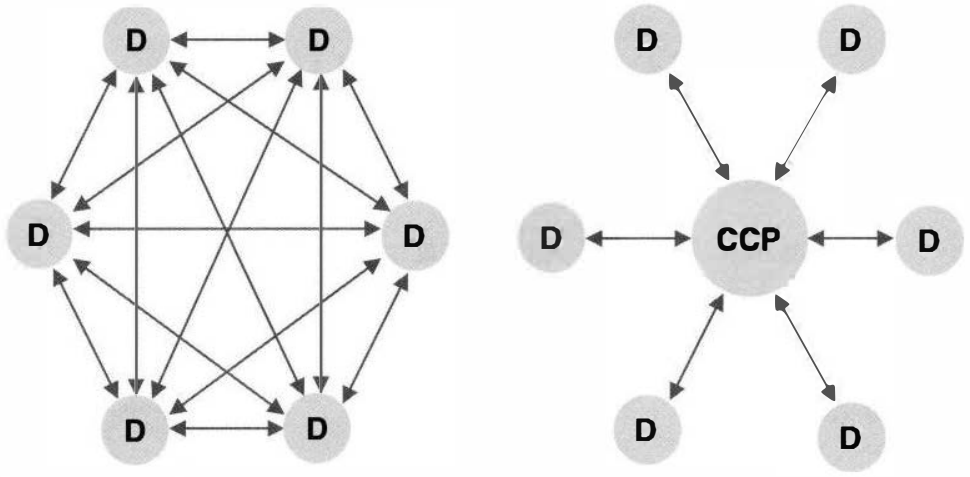

FIGURE 17-2 Illustration of bilateral markets (left) compared to centrally cleared markets (right).

between the original parties ceases to exist and they therefore do not have counterparty risk to one another.

Because it stands between market buyers and sellers, the CCP has a 'matched book' and bears no net market risk, which remains with the original party to each trade. The CCP, on the other hand, does take the counterparty risk, which is centralised in the CCP structure. Put another way, the CCP has 'conditional market risk' since in the event of a member default, it will no longer have a matched book. In order to return to a matched book, a CCP will have various methods, such as holding an auction of the defaulting member's positions. CCPs also mitigate counterparty risk by demanding financial resources from their members that are intended to cover the potential losses in the event that one or more of them default.

Multilateral Offset

A major problem with bilateral clearing is the proliferation of overlapping and potentially redundant contracts, which increases counterparty risk and adds to the interconnectedness of the financial system. Redundant contracts have generally arisen historically because counterparties may enter into offsetting trades, rather than terminating the original one. For dealers, this redundancy may be even more problematic as they may hedge contracts with similar, but not identical, ones.

The first advantage of central clearing is multilateral offset.[1] This offset can be in relation to various aspects such as cashflows or margin requirements. In simple terms, multilateral offset is as illustrated in Figure 17-3. In the bilateral market, the three participants have liabilities marked by the directions of the arrows. The total liabilities to be paid are 180. In this market, A is exposed to C by an amount of 90. If C fails then there is the risk that A may fail also, creating a domino effect. Under central clearing, all assets and liabilities are taken over by the CCP and can offset one another. This means that total risks are reduced: not only is the liability of C offset to 60 but also the insolvency of C can no longer cause a knock-on effect to A since the CCP has intermediated the position between the two.

Whilst the above representation is generally correct, it ignores some key effects. These are the impact of multiple CCPs, the impact of non-cleared trades and even the impact on non-derivatives positions.

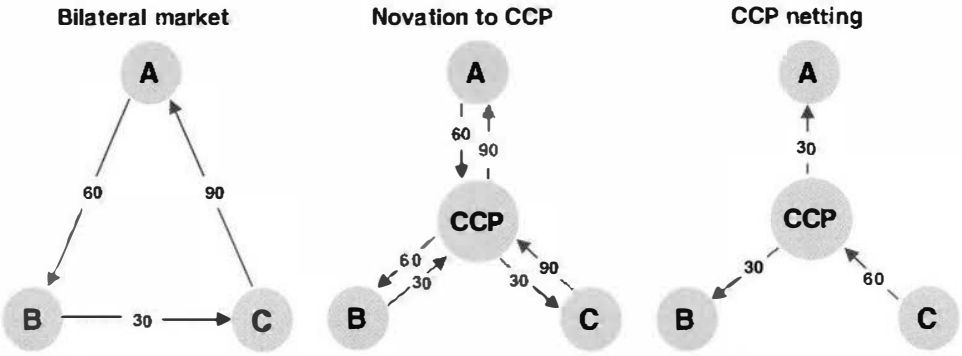

FIGURE 17-3 Illustration of multilateral offsetting afforded by central clearing.

[1] Although there are other bilateral methods that can achieve this such as trade compression.

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Margining

Given that CCPs sit at the heart of large financial markets, it is critical that they have effective risk control and adequate financial resources. The most obvious and important method for this is via the margins that CCPs charge to cover the market risk of the trades they clear. Margin comes in two forms as illustrated in Figure 17-4. Variation margin covers the net change in market value of the member's positions. Initial margin is an additional amount, which is charged at trade inception, and is designed to cover the worst-case close out costs (due to the need to find replacement transactions) in the event a member defaults.

Margin requirements by CCPs are in general much stricter than in bilateral derivative markets. In particular, variation margin has to be transferred on a daily or even intra-daily basis, and must usually be in cash. Initial margin requirements may also change frequently with market conditions and must be provided in cash or liquid assets (e.g., treasury bonds). The combination of initial margins and increased required liquidity of margin, neither of which has historically been a part of bilateral markets, means that clearing potentially imposes significantly higher costs via margin requirements.

Another important point to note on margin requirements is that CCPs generally set margin levels solely on the risks of the transactions held in each member's portfolio. Initial margin does not depend significantly on the credit quality of the institution posting it: the most creditworthy institution may need to post just as much initial margin as others more likely to default. Two members clearing the same portfolio may have the same margin requirements even if their total balance sheet risks are quite different.

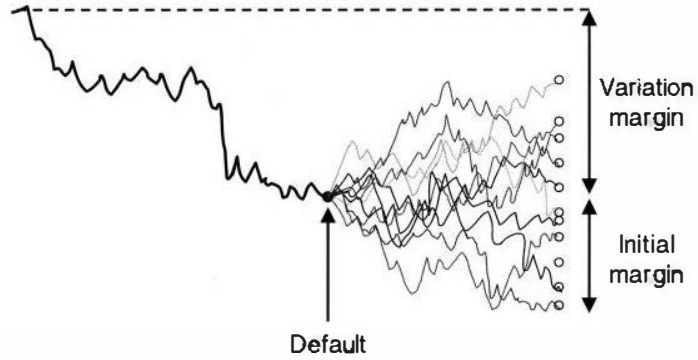

FIGURE 17-4 Illustration of the role of initial and variation margins. Variation margin tracks the value prior to default and initial margin provides a cushion against potential losses after default (e.g. close out costs).

Auctions

In a CCP world, the failure of a counterparty, even one as large and interconnected as Lehman Brothers, is supposedly less dramatic. This is because the CCP absorbs the 'domino effect' by acting as a central shock absorber. In the event of default of one of its members, a CCP will aim to terminate swiftly all financial relations with that counterparty without suffering any losses. From the point of view of surviving members, the CCP guarantees the performance of their trades. This will normally be achieved not by closing out trades at their market value but rather by replacement of the defaulted counterparty with one of the other clearing members for each trade. This is typically achieved via the CCP auctioning the defaulted members' positions amongst the other members.

Assuming they wish to continue doing business with the CCP, members may have strong incentives to participate in an auction in order to collectively achieve a favourable workout of a default without adverse consequences such as making losses through default funds or other mechanisms. This means that the CCP may achieve much better prices for essentially unwinding/novating trades than a party attempting to do this in a bilaterally cleared market. However, if a CCP auction fails then the consequences are potentially severe as other much more aggressive methods of loss allocation may follow.

Loss Mutualisation

The ideal way for CCP members to contribute financial resources is in a 'defaulter pays' approach. This would mean that any clearing member would contribute all the necessary funds to pay for their own potential future default. This is impractical though, because it would require very high financial contributions from each member, which would be too costly. For this reason, the purpose of financial contributions from a given member is to cover losses to a high level of confidence in a scenario where they would default. This leaves a small chance of losses not following the 'defaulter pays' approach and thus being borne by the other clearing members.

Another basic principle of central clearing is that of loss mutualisation, where losses above the resources

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contributed by the defaulter are shared between CCP members. The most obvious way in which this occurs is that CCP members all contribute into a CCP 'default fund' which is typically used after the defaulter's own resources to cover losses. Since all members pay into this default fund, they all contribute to absorbing an extreme default loss.

Note that in a CCP, the default losses that a member incurs are not directly related to the transactions that this member executes with the defaulting member. Indeed, a member can suffer default losses even if it never traded with the defaulted counterparty, has no net position with the CCP, or has a net position with the CCP in the same direction as the defaulter (although there are other potential methods of loss allocation that may favour a member in this situation).

Loss mutualisation is a form of insurance. It is well known that such risk pooling can have positive benefits such as allowing more participants to enter a market. It is equally well known, however, that such mechanisms are also subject to a variety of incentive and informational problems, most notably moral hazard and adverse selection.

BASIC QUESTIONS

What Can Be Cleared?

Quite a large proportion of the OTC derivatives market will be centrally cleared in the coming years (and indeed quite a large amount is already cleared). This is practical since some clearable products (e.g. interest rate swaps) make up such a large proportion of the total outstanding notional. Although clearing is being extended to cover new products, this is a slow process since a product needs to have a number of features before it is clearable.

For a transaction to be centrally cleared, the following conditions are generally important:

- *Standardisation:* Legal and economic terms must be standard since clearing involves contractual responsibility for cashflows.
- *Complexity:* Only vanilla (or non-exotic) transactions can be cleared as they need to be relatively easily and robustly valued on a timely basis to support variation margin calculation.
- *Liquidity:* Liquidity of a product is important so that risk assessments can be made to determine how much initial margin and default fund contribution should be charged. In addition, illiquid products may be difficult to replace in an auction in the event of the default of a clearing member. Finally, if a product is not widely traded then it may not be worthwhile for a CCP to invest in developing the underlying clearing capability because they do not stand to clear enough trades to make the venture profitable.

For an actively traded instrument, there is a large volume of transactions and positions that can be robustly valued or 'marked to market' in a timely fashion. Moreover, extensive historical data is readily available to calibrate risk models, and the liquidity of the market will permit relatively straightforward close out in case of the default of a market participant. For such instruments, central clearing is straightforward. Things are different for instruments that are more complex and/or traded in less liquid markets, meaning that current market price information is harder to come by. Indeed, it may be necessary to use quite complex models in order to value these transactions. Such valuations are relatively subjective, leading to much more uncertainty in evaluating their risks and closing them out in default where the underlying market may be very illiquid.

At the current time, there are OTC derivatives that have been centrally cleared for some time (e.g. interest rate swaps), those that have been recently cleared (e.g. index credit default swaps), those that are on the way to being centrally cleared (e.g. interest rate swaptions, inflation swaps and single-name credit default swaps). Finally, there are of course products that are a long way away and indeed may never be centrally cleared (e.g., Asian options, Bermudan swaptions and interest rate swaps involving illiquid currencies).

Since it is likely that a material proportion of OTC derivatives will not be centrally cleared, it is relevant to re-draw the simplistic diagram showing the potential bilateral connections that exist for non-cleared trades (Figure 17-5).

Who Can Clear?

Only clearing members can transact directly with a CCP. Becoming a clearing member involves meeting a number of requirements and will not be possible for all parties. Generally, these requirements fall into the following categories:

- *Admission criteria:* CCPs have various admission requirements such as credit rating strength (e.g.,

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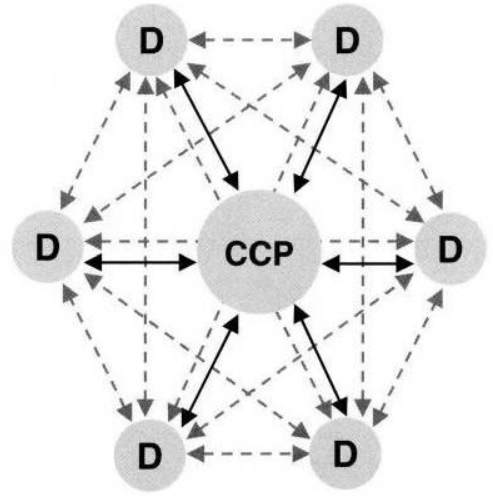

FIGURE 17-5 Illustration of a centrally cleared market with bilateral transactions still existing between members (D). Solid lines represent CCP cleared trades and dotted lines bilateral ones.

triple-B minimum) and requirements that members have a sufficiently large capital base (e.g., US$50 million).

- *Financial commitment:* Members must contribute to the CCP's default fund. Whilst such contributions will be partly in line with the trading activity, there may be a minimum commitment and it is likely that only institutions intending to execute a certain volume of trades will consider this default fund contribution worthwhile.
- *Operational:* Being a member of a CCP has a number of operational requirements associated to it. One is the frequent posting of liquid margin and others are the requirement to participate in 'fire drills' which simulate the default of a member, and auctions in the event a member does indeed default.

The impact of the above is that large global banks and some other very large financial institutions are likely to be clearing members whereas smaller banks, buy side and other financial firms, and other non-financial end users are unlikely to be direct clearing members. Large global banks will fulfill their role as prime brokers by being members of multiple CCPs globally so as to offer a full choice of clearing services to their clients. Large regional banks may be members of only a local CCP so as to support domestic clearing services for their clients.

Institutions that are not CCP members, so-called non-clearing members ('clients'), can clear through a clearing member. This can work in two ways: so-called principal-to-principal or agency methods. The general rule, though, is that the client effectively has a direct bilateral relationship with their clearing member and not the CCP. Clients will generally still have to post margin, but will not be required to contribute to the CCP default fund. Clearing members will charge their clients (explicitly and implicitly) for the clearing service that they provide, which will include elements such as the subsidisation of the default fund. The position of clearing members to their clients is still bilateral and so would normally be unchanged. However, it is likely that clearing members will partially 'mirror' CCP requirements in their bilateral client relationships, for example in relation to margin posting.

Updating the CCP landscape to include non-clearing members leads to the illustration shown in Figure 17-6. It is important to note that non-clearing members (C) will likely have relationships with more than one clearing member.

Many questions arise regarding the risks that clients face in this clearing structure. What is key in this respect is the way in which margin posted by the client is passed through to the clearing member, and/or the CCP, and how it is segregated. Depending on this, it is possible for the client to have risk to the CCP, their clearing member, or their clearing member together with other clients of their clearing member. Another closely related question is one of 'portability', which refers to a client being able to transfer ('port') their positions to another clearing member (for example in the event of default by their original clearing member).

It is often stated that CCPs will reduce the interconnections between institutions, especially those that are systemically important. However, as seen in Figure 17-6, CCPs will rather change the connections—potentially in a favourable way, of course.

How Many OTC CCPs Will There Be?

A large number of CCPs will maximise competition but could lead to a race to the bottom in terms of cost, leading to a much more risky CCP landscape. Having a small number of CCPs is beneficial in terms of offsetting benefits and economies of scale. Whilst a single global CCP is clearly optimal for a number of reasons, it seems likely

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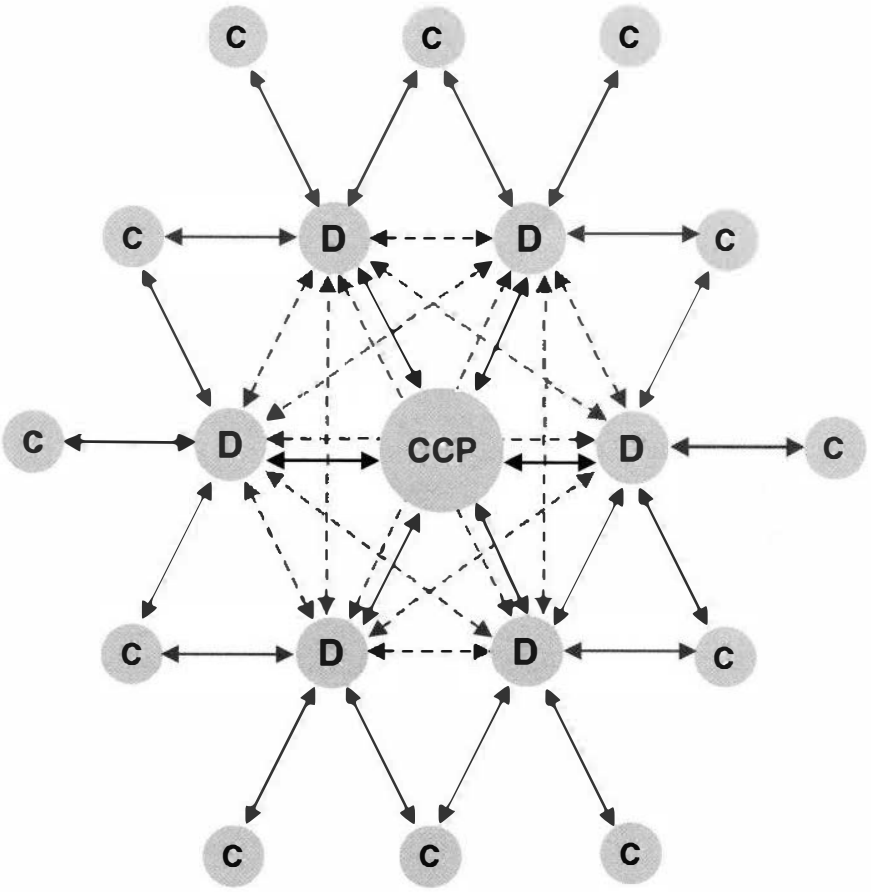

FIGURE 17-6 Illustration of a centrally cleared market, including the position of non-clearing members (C) who clear through clearing members (D).

that the total number of CCPs will be relatively large. This is due to bifurcation on two levels:

- *Regional*. Major geographical regions view it as important to have their own 'local' CCPs, either to clear trades denominated in their own currency or all trades executed for financial institutions in that region. Indeed, regulators in some regions require that financial institutions under their supervision clear using their own regional CCP.
- *Product*. CCPs clearing OTC derivatives have tended to act as vertical structures and specialise in certain product types (e.g. interest rate swaps or credit default swaps) and thus there is no complete solution of one CCP that can offer coverage of every clearable product.

An illustration of the impact of multiple CCPs is shown in Figure 17-7. A key feature is that clearing members of one CCP may well be members of another also. Additionally, there may be a need for *interoperability* between CCPs. Interoperability may be important to circumvent regulatory requirements such as two regulators requiring trades to be cleared through regional CCPs. It may also improve the efficiency of clearing by recognising offsetting positions between CCPs, leading, for example, to lower margin requirements. However, interoperability will increase interconnectedness in financial markets, potentially increasing systemic risk.

Utilities or Profit-Making Organisations?

Clearing trades obviously has an associated cost. CCPs cover this cost by charging fees per trade and by deriving interest from margins they hold. As fundamental market infrastructures and nodes of the financial system, CCPs clearly need to be resilient, especially during major financial

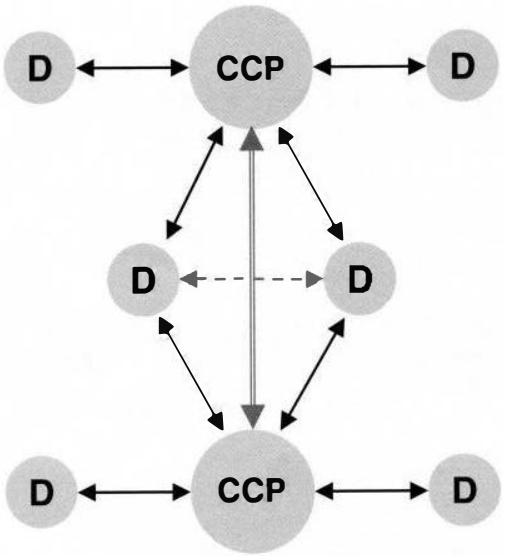

FIGURE 17-7 Illustration of a centrally cleared market with two CCPs. The dotted line represents bilateral trades. Interoperability between the CCPs is also shown.

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disturbances. This may imply that a utility CCP driven by long-term stability and not short-term profits may be a preferable business model. However, it could also be argued that CCPs will need to have the best personnel and systems to be able to develop the advanced risk management and operational capabilities. Moreover, competition between CCPs will benefit users and provide choice. Expertise and competition implies that CCPs should be profit-making organisations. Clearly, this introduces a risk of a possible race to the bottom with respect to certain practices (e.g., margin calculations) that could increase the risk posed by CCPs.

Can CCPs Fail?

The failure of a large and complex CCP, such as one clearing many OTC derivatives, would represent an event potentially worse than the failure of financial institutions such as Lehman Brothers. Furthermore, a bailout of a CCP could be a more complex and sizable task than even bailouts of banks and financial institutions such as Bear Steams and AIG. CCPs must therefore maintain financial resources, such as initial margins and default funds, to absorb losses in all but extreme situations. In such extreme situations, CCPs need to have loss allocation methods that aim to absorb losses beyond their financial resources in a manner that does not create or exasperate systemic market disturbances. Of course, it is still a possibility that a CCP's financial resources may be breached, and they are unable to recover via some loss allocation process. In such a situation, the provision of liquidity support from a central bank must be considered. Regulators seem to accept that systemically important CCPs would need such support although only as a last resort.[2]

THE IMPACT OF CENTRAL CLEARING

General Points

It is useful to discuss some of the general advantages and disadvantages of OTC CCPs now. Important points to make in relation to OTC central clearing are:

- A CCP is not a panacea for the perceived problems in the OTC derivatives market.
- A CCP does not make counterparty risk disappear. What it does is centralise it and convert it into different forms of financial risk such as operational and liquidity.
- As with most things, for every advantage of a CCP, there are related disadvantages. For example, CCPs can *reduce* systemic risk (via auctions for example) but can also *increase* it (for example by changing margin requirements in volatile markets).
- CCPs provide a variety of functions, most of which can already be achieved by bilateral markets via other mechanisms. CCPs may or may not execute redundant functions more efficiently and CCP-specific functionality offers advantages and disadvantages.
- Central clearing may be beneficial overall for some markets but not others.
- There are likely to be unintended consequences of the expanded use of CCPs, which are hard to predict a priori.
- Like any financial institution, CCPs can fail, and indeed there are historical CCP insolvencies from which to learn (Chapter 18).

Comparing OTC and Centrally Cleared Markets

Table 17-1 compares OTC markets with CCP and exchange-based ones. In CCP markets, whilst trades are still executed bilaterally, there are many differences that are required by central clearing, such as the need for standardisation, margining practices and the use of mutualised default funds to cover losses. Exchange-traded markets are similar to CCP ones except that in the former case the trade is executed on the exchange rather than beginning life as a bilateral trade.

Advantages of CCPs

CCPs offer many advantages and potentially offer a more transparent, safer market where contracts are more fungible and liquidity is enhanced. The following is a summary of the advantages of a CCP:

- *Transparency:* A CCP is in a unique position to understand the positions of market participants. This may disperse panic that might otherwise be present in bilateral markets due to a lack of knowledge of the exposure faced by institutions. If a member has a

[2] For example, see 'BeE's Camey: liquidity support for CCPs is a "last-resort" option', *Risk*, November 2013, http://www.risk.net/risk-magazine/news/2309908/boes-camey-liquidity-support-for-ccps-is-a-last-resort-option.

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TABLE 17-1 Comparing OTC Derivatives Markets with CCP and Exchange-Traded Markets

	OTC	CCP	Exchange
Trading	Bilateral	Bilateral	Centralised
Counterparty	Original	CCP	
Products	All	Must be standard, vanilla, liquid, etc.	
Participants	All	Clearing members are usually large dealers Other margin posting entities can clear through clearing members	
Margining	Bilateral, bespoke arrangements dependent on credit quality and open to disputes	Full margining. including initial margin enforced by CCP	
Loss buffers	Regulatory capital and margin (where provided)	Initial margins, default funds and CCP own capital	

particularly extreme exposure, the CCP is in a position to act on this and limit trading (for example by charging larger margins).

- *Offsetting:* As mentioned above, contracts transacted between different counterparties but traded through a CCP can be offset. This increases the flexibility to enter new transactions and terminate existing ones, and reduces costs.
- *Loss mutualisation:* Even when a default creates losses that exceed the financial commitments from the defaulter, these losses are distributed throughout the CCP members, reducing their impact on any one member. Thus a counterparty's losses are dispersed partially throughout the market, making their impact less dramatic and reducing the possibility of systemic problems.
- *Legal and operational efficiency:* The margining, netting and settlement functions undertaken by a CCP potentially increase operational efficiency and reduce costs. CCPs may also reduce legal risks in providing a centralisation of rules and mechanisms.
- *Liquidity:* A CCP may improve market liquidity through the ability of market participants to trade easily and benefit from multilateral netting. Market entry may be enhanced through the ability to trade anonymously and through the mitigation of counterparty risk. Daily margining may lead to a more transparent valuation of products.
- *Default management:* A well-managed central auction may result in smaller price disruptions than the uncoordinated replacement of positions during a crisis period associated with default of a clearing member.

Disadvantages of CCPs

A CCP, by its very nature, represents a membership organisation, which therefore results in the pooling of member resources to some degree. This means that any losses due to the default of a CCP member may to some extent be shared amongst the surviving members, and this lies at the heart of some potential problems. The following is a summary of the disadvantages of a CCP:

- *Moral hazard:* This is a well-known problem in the insurance industry. Moral hazard has the effect of disincentivising good counter-party risk management practice by CCP members (since all the risk is passed to the CCP). Institutions have little incentive to monitor each other's credit quality and act appropriately because a third party is taking most of the risk.
- *Adverse selection:* CCPs are also vulnerable to adverse selection, which occurs if members trading OTC derivatives know more about the risks than the CCP themselves. In such a situation, firms may selectively pass

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these more risky products to CCPs that under-price the risks. Obviously, firms such as large banks specialise in OTC derivatives and may have superior information and knowledge on pricing and risk than a CCP.

- *Bifurcations:* The requirement to clear standard products may create unfortunate bifurcations between cleared and non-cleared trades. This can result in highly volatile cashflows for customers, and mismatches (of margin requirements) for seemingly hedged positions.
- *Procyclicality:* Procyclicality refers to a positive dependence with the state of the economy. CCPs may create procyclicality effects by, for example, increasing margins (or haircuts) in volatile markets or crisis periods. The greater frequency and liquidity of margin requirements under a CCP (compared with less uniform and more flexible margin practices in bilateral OTC markets) could also aggravate procyclicality.

Impact of Central Clearing

Some of the impacts of central clearing are difficult to assess since they may represent both advantages and disadvantages depending on the products and markets in question. There are also aspects in which CCPs may be considered to increase and decrease various financial risks. For example, it is often stated that CCPs will reduce systemic risk. They can clearly do this by providing greater transparency, offsetting positions and dealing with a large default in an effective way. However, they also have the potential to increase systemic risk, for example by increasing margins in turbulent markets. Overall, in accordance with a sort of conservation of risk principal, CCPs will not so much reduce counterparty risk but rather distribute it and convert it into different forms such as liquidity, operational and legal risks. CCPs also concentrate these risks in a single place and therefore magnify the systemic risk linked to their own potential failure.

OTC derivative clearing is fundamentally different from the clearing of other financial transactions (such as spot market securities or forward contracts). Unlike these contracts, which are completed in a few days, OTC derivative contracts (for example, swaps), remain outstanding for potentially years or even decades before being settled. It is not completely obvious that CCPs are as effective in risk mitigation for these longer-dated, more complex and illiquid products. In addition, central clearing for non-standard and/or exotic OTC derivatives may not be feasible. OTC markets have proved over the years that they are a good source of financial innovation and can continue to offer cost-effective and well-tailored risk reduction products. They are also likely to remain important in the future at providing incentives for innovation. There is a risk that mandatory central clearing has a negative impact on the positive role that OTC derivatives play.

A final point to note is that even if CCPs make OTC derivatives safer, this does not necessarily translate into more stable financial markets in general. The mechanisms used by a CCP, such as netting and margining, protect OTC derivative counterparties at the expense of other creditors. Furthermore, a CCP's beneficial position in being able to define their own rules and having preferential treatment with respect to aspects such as bankruptcy laws comes at a detriment to other parties. These distributive effects of central clearing are often overlooked. It is also important to note that financial markets have a tendency to adjust rapidly, especially in response to a significant regulatory mandate. It might be argued that CCPs can make OTC derivative markets safer. However, even if this is true then it cannot be extrapolated to imply that they will definitely enhance financial market stability in general.

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Risks Caused by CCPs: Risks Faced by CCPs

18

Learning Objectives

After completing this reading you should be able to:

- Identify and explain the types of risks faced by CCPs.
- Identify and distinguish between the risks to clearing members as well as non-members.
- Identify and evaluate lessons learned from prior CCP failures.

Excerpt is Chapter 14 of Central Counterparties: Mandatory Clearing and Bilateral Margin Requirements for OTC Derivatives, *by Jon Gregory.*

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RISKS FACED BY CCPs

Default Risk

The key risk for a CCP is the default of a clearing member and, more importantly, the possible associated or knock-on effects that this could cause. In particular, the fear factor in the aftermath of a default event could create further problems such as:

- *Default or distress of other clearing members*: Given the nature of participants in the OTC derivatives market, default correlation would be expected to be high and defaults unlikely to be idiosyncratic events.
- *Failed auctions*: If CCP does not receive reasonable economic bids in an auction, then it faces imposing significant losses of its member via rights of assessment and/or alternative loss allocation methods (e.g., VMGH, tear-up or forced allocation). Imposing losses on other clearing members will potentially calalyse financial distress of these members, even possibly leading to further defaults.
- *Resignations*: It is possible for clearing members to leave a CCP, which they would be most likely to do in the aftermath of a default, although this cannot be immediate (typically a member would need to flatten their cleared portfolio and give a pre-defined notice period such as one month). However, since initial margins and default funds would need to be returned to a resigning clearing member,[1] their loss could be felt in real terms as well as the potential negative reputational impact it may cause with respect to other members.
- *Reputational*: Remedying a clearing member default may involve relatively extreme loss allocation methods. Even if this ensures the viability and continuation of the CCP, the methodology for assigning losses may be considered unfair by certain clearing members and their clients. Methods such as VMGH and tear-ups may be viewed as imposing losses on them simply because they have winning positions. These positions may not of course be winning overall as they may be balanced by other transactions (bilateral or at a different CCP). They may also be client trades that are executed as hedges for commercial risk. The negative views in relation to such loss allocation could cause problems and may have consequences such as resignations.

[1] At the time of leaving a CCP, despite having a flat book a clearing member may still have to be returned excess initial margin deposited. Furthermore, they would likely still have some default fund contribution to be returned as this may not be driven entirely by the risk of their portfolio at the time (e.g., it may be related to trading volumes over a previous period).

Non-Default Loss Events

CCPs could potentially suffer losses from other non-default events, which is important since they handle large amounts of cash and other securities. Examples of potentially significant loss events could be:

- *Fraud*: Internal or external fraud.
- *Operational*: Operational losses could arise due to business disruption linked to aspects such as systems failures.
- *Legal*: Losses due to litigation or legal claims including the risk that the law in a given jurisdiction does not support the rules of the CCP. For example, if netting and margining terms are not protected by regional laws.
- *Investment*: Losses from investments of cash and securities held as margin and other financial resources within the investment policy, or due to a deviation from this policy (e.g., a rogue trader).

It is also likely that non-default losses and default losses may be correlated and therefore potentially hit the CCP concurrently. One reason for this is that a default scenario is likely to cause a significant market disturbance and increase the likelihood of operational and investment problems. Furthermore, the large spread of potential winners and losers in a default scenario increases the risk of legal challenges and fraudulent activity.

Model Risk

CCPs have significant exposure to model risk through margining approaches. Unlike exchange-traded products, OTC derivatives prices often cannot be observed directly via market sources. This means that valuation models are required to mark-to-market products for variation margin purposes. The approaches for marking-to-market must be standard and robust across all possible market scenarios. If this is not the case then timely variation margin calls may be compromised.

CCPs are probably most exposed to model risk via their initial margin approaches. Particular modelling problems could arise from misspecification with respect to volatility, tail risk, complex dependencies and wrong-way risk.

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For example. an adverse correlation across market and credit risks could mean that a CCP could be faced with liquidating positions in a situation where there are significant market moves. A lesson from previous CCP failures is that initial margin methodologies need to be updated as a market regime shifts significantly. On the other hand, such updates should not be excessive as they can lead to problems such as procyclicality.

Another important feature of models is that they generally impose linearity. For example, model-based initial margins will increase in proportion to the size of a position. It is important in this situation to use additional components such as margin multipliers to ensure that large and concentrated positions are penalised and their risk is adequately covered. This is an example of qualitative adjustments to quantitative models being important.

Liquidity Risk

A CCP faces liquidity risk due to the large quantities of cash that flow through them due to variation margin payments and other cashflows. CCPs must try to optimise investment of some of the financial resources they hold, without taking excessive credit and liquidity risk (e.g., by using short-term investments such as deposits, repos and reverse repos). However, in the event of a default, the CCP must continue to fulfil its obligations to surviving members in a timely manner.

Although CCPs will clearly invest cautiously over the short term, with liquidity and credit risk very much in mind, there is also the danger that the underlying investments they hold must be readily available and convertible into cash. In attempting to secure prearranged and highly reliable funding arrangements, the sheer size of CCP initial margin holdings may be difficult. For example, a typical credit facility may extend at most to billions of dollars whilst some large CCPs will easily hold tens of billions in initial margins. If a CCP does not have liquidity support from, for example, a central bank then this could be problematic.

Such potential liquidity problems seem to already be in the mind of regulators. The CPSS-IOSCO (2012) principals require a CCP to have enough liquid resources to meet obligations should one or two of its largest clearing members collapse. Under this guidance, bonds (including government securities) may only be counted towards a CCP's liquidity resources if they are backed with committed funding arrangements, so that they can be converted into cash immediately. For example, in the US, the Commodity Futures Trading Commission (CFTC) has further defined this as 'readily available and convertible into cash pursuant to prearranged and highly reliable funding arrangements, even in extreme but plausible market conditions'.[2] This would require CCPs to have committed facilities rather than blindly assuming that they could readily repo securities and would imply, for example, that US treasury securities are not considered to be as good as cash. These rules are controversial, not least since they may not be required by all regulators, and may lead to competitive pressures.[3]

Another liquidity pressure for clearing could come from the Basel III leverage ratio requirements. The leverage ratio is defined as a bank's tier one capital (at least 3%) divided by its exposure and aims to reduce excessive risk taking. The definition of exposure includes the gross notional of centrally cleared OTC derivative transactions. Under the principal-to-principal clearing model used, for example in Europe, a client transaction would be classed as two separate trades (clearing member with client and clearing member with CCP). Potentially, both trades would count towards the leverage ratio further increasing capital requirements.

Whilst the above requirements can be seen as regulators being very aware of the potential liquidity risks that CCPs face, they also run the risk of reducing clearing services offered.[4]

Operational and Legal Risk

The centralisation of various functions within a CCP can increase efficiency but also expose market participants to additional risks, which become concentrated at the CCP. Like all market participants, CCPs are exposed to operational risks, such as systems failures and fraud. A breakdown of any aspect of a CCP's infrastructure would be catastrophic since it would affect a relatively sizeable

[2] CFTC Regulation 39.33 (c)(3)(i), http://www.cftc.gov/LawRegulation/FederalRegister/ProposedRules/2013-19845.

[3] For example, see 'CME threatens to flee US as regulators challenge liquidity of US Treasury collateral', Risk, 5 November 2013, http://www.risk.net/risk-magazinenews/2305083/cme-threatens-to-flee-us-as-regulators-challenge-liquidity-of-us-treasury-collateral.

[4] For example, see 'BNY to shutdown clearing service', International Financing Review, 7 December 2013.

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number of large counterparties within the market. Aspects such as segregation and the movement of margin and positions through a CCP, can be subject to legal risk from laws in different jurisdictions.

Other Risks

Other risks faced by CCPs are:

- *Settlement and payment*: A CCP faces settlement risk if a bank providing an account for cash settlement between the CCP and its members is no longer willing or able to provide it with those services.
- *FX risk*: Due to a potential mismatch between margin payments and cash flows in various currencies (although CCPs typically require variation margin in cash in the transaction currency).
- *Custody risk*: In case of the failure of a custodian.
- *Concentration risk*: Due to having clearing members and/or margins exposed to a single region.
- *Sovereign risk*: Having direct exposure to the knock-on effects of a sovereign failure in terms of the failure of members and devaluation of sovereign bonds held as margin.
- *Wrong-way risk*: Due to unfavourable dependencies. such as between the value of margin held and creditworthiness of clearing members.

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Foreign Exchange Risk

19

Learning Objectives

After completing this reading you should be able to:

- Calculate a financial institution's overall foreign exchange exposure.
- Explain how a financial institution could alter its net position exposure to reduce foreign exchange risk.
- Calculate a financial institution's potential dollar gain or loss exposure to a particular currency.
- Identify and describe the different types of foreign exchange trading activities.
- Identify the sources of foreign exchange trading gains and losses.
- Calculate the potential gain or loss from a foreign currency denominated investment.
- Explain balance-sheet hedging with forwards.
- Describe how a non-arbitrage assumption in the foreign exchange markets leads to the interest rate parity theorem, and use this theorem to calculate forward foreign exchange rates.
- Explain why diversification in multicurrency asset-liability positions could reduce portfolio risk.
- Describe the relationship between nominal and real interest rates.

Excerpt is Chapter 13 of Financial Institutions Management: A Risk Management Approach, *Eighth Edition, by Anthony Saunders and Marcia Millon Cornett.*

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INTRODUCTION

The globalization of the U.S. financial services industry has meant that FIs are increasingly exposed to foreign exchange (FX) risk. FX risk can occur as a result of trading in foreign currencies, making foreign currency loans (such as a loan in pounds to a corporation), buying foreign-issued securities (U.K. pound denominated gilt-edged bonds or German euro-government bonds), or issuing foreign currency-denominated debt (pound certificates of deposit) as a source of funds. Extreme foreign exchange risk at a single FI was evident in 2002 when a single trader at Allfirst Bank covered up $700 million in losses from foreign currency trading. After five years in which these losses were successfully hidden, the activities were discovered in 2002. More recently, in 2012 a strengthening dollar reduced profits for internationally active firms. For example, IBM experienced a drop in revenue of 3 percent due to foreign exchange trends. Similarly, Coca-Cola, which gets the majority of its sales from outside the United States, saw 2012 revenues decrease by approximately 5 percent as the U.S. dollar strengthened relative to foreign currencies.

This chapter looks at how FIs evaluate and measure the risks faced when their assets and liabilities are denominated in foreign (as well as in domestic) currencies and when they take major positions as traders in the spot and forward foreign currency markets.

FOREIGN EXCHANGE RATES AND TRANSACTIONS

Foreign Exchange Rates

A foreign exchange rate is the price at which one currency (e.g., the U.S. dollar) can be exchanged for another currency (e.g., the Swiss franc). Table 19-1 lists the exchange rates between the U.S. dollar and other currencies as of 4 PM eastern standard time on July 4, 2012. Foreign exchange rates are listed in two ways: U.S. dollars received for one unit of the foreign currency exchanged, or a **direct quote** (in US$), and foreign currency received for each U.S. dollar exchanged, or an **indirect quote** (per US$). For example, the exchange rate of U.S. dollars for Canadian dollars on July 4, 2012 was 0.9870 (US$/C$), or $0.9870 could be received for each Canadian dollar exchanged. Conversely, the exchange rate of Canadian dollars for U.S. dollars was 1.0131 (C$/US$), or 1.0131 Canadian dollars could be received for each U.S. dollar exchanged.

Foreign Exchange Transactions

There are two basic types of foreign exchange rates and foreign exchange transactions: spot and forward. **Spot foreign exchange transactions** involve the immediate exchange of currencies at the current (or spot) exchange rate (see Figure 19-1). Spot transactions can be conducted through the foreign exchange division of commercial banks or a nonbank foreign currency dealer. For example, a U.S. investor wanting to buy British pounds through a local bank on July 4, 2012 essentially has the dollars transferred from his or her bank account to the dollar account of a pound seller at a rate of $1 per 0.6414 pound (or $1.5591 per pound).[1] Simultaneously, pounds are transferred from the seller's account into an account designated by the U.S. investor. If the dollar depreciates in value relative to the pound (e.g., $1 per 0.6360 pound or $1.5723 per pound), the value of the pound investment, if converted back into U.S. dollars, increases. If the dollar appreciates in value relative to the pound (e.g., $1 per 0.6433 pound or $1.5545 per pound), the value of the pound investment, if converted back into U.S. dollars, decreases.

The exchange rates listed in Table 19-1 all involve the exchange of U.S. dollars for the foreign currency, or vice versa. Historically, the exchange of a sum of money into a different currency required a trader to first convert the money into U.S. dollars and then convert it into the desired currency. More recently, cross-currency trades allow currency traders to bypass this step of initially converting into U.S. dollars. Cross-currency trades are a pair of currencies traded in foreign exchange markets that do not involve the U.S. dollar. For example, GBP/JPY cross-exchange trading was created to allow individuals in the United Kiingdom and Japan who wanted to convert their money into the other currency to do so without having to bear the cost of having to first convert into U.S. dollars. Cross-currency exchange rates for eight major countries are listed at Bloomberg's website: **www.bloomberg.com/markets/currencies/fxc.html**.

The appreciation of a country's currency (or a rise in its value relative to other currencies) means that the

[1] In actual practice, settlement—exchange of currencies—occurs normally two days after a transaction.

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TABLE 19-1 Foreign Currency Exchange Rates

Currencies

U.S.-dollar foreign-exchange rates in late New York trading

Country/Currency	Wed In US$	Wed per US$	US$ vs, YTD chg %	Country/Currency	Wed In US$	Wed per US$	US$ vs, YTD chg %
Americas				*Europe*			
Argentina peso*	.2211	4.5234	5.0	Czech. Rep. koruna**	.04907	20.378	3.2
Brazil real	.4932	2.0278	8.7	Denmark krone	.1684	5.9367	3.5
Canada dollar	.9870	1.0131	−0.8	Euro area euro	1.2527	.7983	3.5
Chile peso	.002015	496.40	−4.5	Hungary forint	.004378	228.41	−6.1
Colombia peso	.0005650	1770.00	−8.8	Norway krone	.1670	5.9891	0.2
Ecuador US dollar	1	1	unch	Poland zloty	.2971	3.3656	−2.4
Mexico peso*	.0750	13.3339	−4.4	Russia ruble‡	.03093	32.331	0.6
Peru new sol	.3785	2.642	−2.0	Sweden krona	.1447	6.9106	0.4
Uruguay peso†	.04597	21.7520	9.8	Switzerland franc	1.0428	.9589	2.3
Venezuela b.fuerte	.229885	4.3500	unch	1-month forward	1.0436	.9582	2.2
Asia-Pacific				3-months forward	1.0455	.9565	2.2
Australian dollar	1.0277	.9731	−0.7	6-months forward	1.0483	.9539	2.2
1-month forward	1.0254	.9761	−0.7	Turkey lira**	.5533	1.8073	−5.7
3-months forward	1.0186	.9817	−0.8	U.K. pound	1.5591	.6414	−0.3
6-months forward	1.0110	.9891	−0.9	1-month forward	1.5590	.6414	−0.3
China yuan	.1575	6.3486	0.5	3-months forward	1.5588	.6415	−0.4
Hong Kong dollar	.1289	7.7551	−0.2	6-months forward	1.5584	.6417	−0.5
India rupee	.01833	54.545	2.9	*Middle East/Africa*			
Indonesia rupiah	.0001070	9343	3.4	Bahrain dinar	2.6528	.3770	unch
Japan yen	.012520	79.87	3.8	Egypt pound*	.1650	6.0610	0.2
1-month forward	.012524	79.84	3.7	Israel shekel	.2550	3.9220	2.9
3-months forward	.012535	79.78	3.8	Jordan dinar	1.4119	.7083	−0.2
6-months forward	.012553	79.66	3.8	Kuwait dinar	3.5632	.2806	0.9
Malaysia ringgit	.3171	3.1538	−0.7	Lebanon pound	.0006641	1505.70	unch
New Zealand dollar	.8037	1.2443	−3.2	Saudi Arabia riyal	.2667	3.7501	unch
Pakistan rupee	.01058	94.500	5.2	South Africa rand	.1229	8.1386	0.6
Philippines peso	.0240	41.654	−5.0	UAE dirham	.2723	3.6730	unch
Singapore dollar	.7897	1.2661	−2.3				
South Korea won	.0008793	1137.30	−2.0				

*Floating rate †Financial ‡Russian Central Bank rate **Rebased as of Jan 1, 2005

Note: Based on trading among banks of $1 million and more, as quoted at 4p.m. ET by Reuters.

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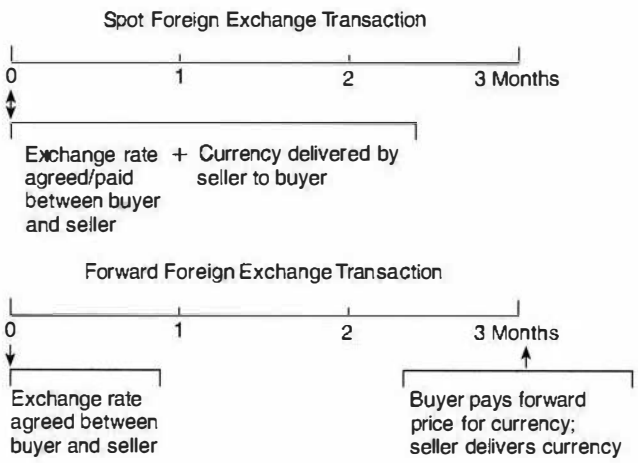

FIGURE 19-1 Spot versus forward foreign exchange transaction.

country's goods are more expensive for foreign buyers and that foreign goods are cheaper for foreign sellers (all else constant). Thus, when a country's currency appreciates, domestic manufacturers find it harder to sell their goods abroad and foreign manufacturers find it easier to sell their goods to domestic purchasers. Conversely, depreciation of a country's currency (or a fall in its value relative to other currencies) means the country's goods become cheaper for foreign buyers and foreign goods become more expensive for foreign sellers. Figure 19-2 shows the pattern of exchange rates between the U.S. dollar and several foreign currencies from 2003 through June 2012. Notice the significant swings in the exchange rates of foreign currencies relative to the U.S. dollar during the financial crisis. Between September 2008 and mid-2010, exchange rates went through three trends. During the first phase, from September 2008 to March 2009, the U.S. dollar appreciated relative to most foreign currencies (or, foreign currencies depreciated relative to the dollar) as investors sought a safe haven in U.S. Treasury securities. During the second phase, from March 2009 through November 2009, much of the appreciation of the dollar relative to foreign currencies was reversed as worldwide confidence returned. Between November 2009 and June 2010, countries (particularly those in the eurozone) began to see depreciation relative to the dollar resume (the dollar appreciated relative to the euro) amid concerns about the euro, due to problems in various EU countries (such as Portugal, Ireland, Iceland, Greece, and Spain, the so-called PIIGS). From June 2010 through August 2011, worries about Europe subsided somewhat, and the U.S. government struggled to pass legislation allowing an increase in the national debt ceiling that would allow the country to avoid a potential default on U.S. sovereign debt. The dollar depreciated against many foreign currencies until a debt ceiling increase was passed on August 2, 2011. Despite a downgrade in the rating on the U.S. debt by Standard & Poor's on August 5, 2011 (resulting from the inability of the U.S. Congress to work to stabilize the U.S. debt deficit situation in the long term), the dollar again appreciated relative to most foreign currencies in the period after August 2011 as fears of escalating problems in Europe, including a possible dissolution of the euro, led investors to again seek safe haven in U.S. Treasury securities.

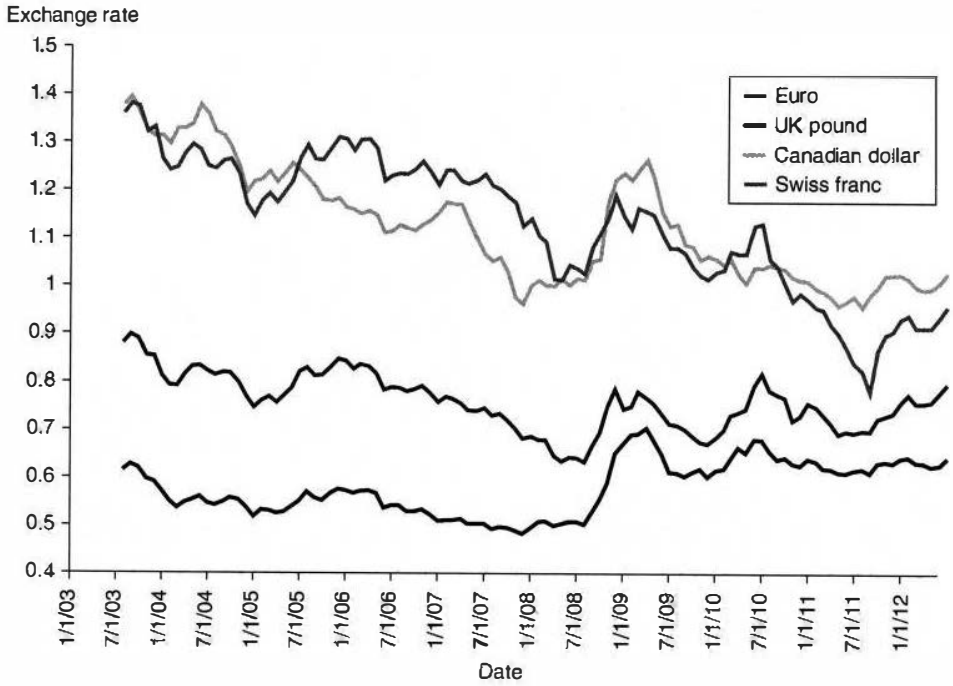

FIGURE 19-2 Exchange rate of U.S. dollars with various foreign currencies.

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A **forward foreign exchange transaction** is the exchange of currencies at a specified exchange rate (or forward exchange rate) at some specified date in the future, as illustrated in Figure 19-1. An example is an agreement today (at time 0) to exchange dollars for pounds at a given (forward) exchange rate three months in the future. Forward contracts are typically written for one-, three-, or six-month periods, but in practice they can be written over any given length of time.

Concept Question

1. What is the difference between a spot and a forward foreign exchange market transaction?

SOURCES OF FOREIGN EXCHANGE RISK EXPOSURE

The nation's largest commercial banks are major players in foreign currency trading and dealing, with large money center banks such as Citigroup and J.P. Morgan Chase also taking significant positions in foreign currency assets and liabilities. Table 19-2 shows the outstanding dollar value of U.S. banks' foreign assets and liabilities for the period 1994 to March 2012. The 2012 figure for foreign assets (claims) was $319.4 billion, with foreign liabilities of $235.3 billion. As you can see, both foreign currency liabilities and assets were growing until 1997 and then fell from 1998 through 2000. The financial crises in Asia and Russia in 1997 and 1998 and in Argentina in the early 2000s are likely reasons for the decrease in foreign assets and liabilities during this period. After this period, growth accelerated rapidly as the world economy recovered. While the growth of liability and asset claims on foreigners slowed during the financial crisis, levels remained stable as U.S. FIs were seen as some of the safest FIs during the crisis. Further, in 1994 through 2000, U.S. banks had more liabilities to than claims (assets) on foreigners. Thus, if the dollar depreciates relative to foreign currencies, more dollars (converted into foreign currencies) would be needed to pay off the liabilities and U.S. banks experience a loss due to foreign exchange risk. However, the reverse was true in 2005 through 2012; that is, as the dollar depreciates relative to foreign currencies, U.S. banks experience a gain from their foreign exchange exposures.

Table 19-3 gives the categories of foreign currency positions (or investments) of all U.S. banks in major currencies as of June 2012. Columns (1) and (2) refer to the assets and liabilities denominated in foreign currencies that are held in the portfolios at U.S. banks. Columns (3) and (4) refer to trading in foreign currency markets (the **spot** market and **forward market for foreign exchange** in which contracts are bought—a long position—and sold—a short

TABLE 19-2 Liabilities to and Claims on Foreigners Reported by Banks in the United States, Payable in Foreign Currencies (in millions of dollars, end of period)

Item	1994	1995	1997	1998	2000	2005	2008	2009	2012*
Banks' liabilities	$89,284	$109,713	$117,524	$101,125	$76,120	$85,841	$290,467	$215,883	$235,300
Banks' claims	60,689	74,016	83,038	78,162	56,867	93,290	324,230	333,622	319,401
Deposits	19,661	22,696	28,661	45,985	22,907	43,868	108,417	97,822	135,211
Other claims	41,028	51,320	54,377	32,177	33,960	49,422	215,813	237,649	184,190
Claims of banks' domestic customers†	10,878	6,145	8,191	20,718	29,782	54,698	42,208	47,236	45,386

Note: Data on claims exclude foreign currencies held by U.S. monetary authorities.

*2012 data are for end of March.

†Assets owned by customers of the reporting bank located in the United States that represent claims on foreigners held by reporting banks for the accounts of the domestic customers.

Source: Federal Reserve Bulletin, Table 3.16, various issues. *www.federalreserve.gov*

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TABLE 19-3 Monthly U.S. Bank Positions in Foreign Currencies and Foreign Assets and Liabilities, March 2012 (in currency of denomination)

	(1) Assets	(2) Liabilities	(3) FX Bought*	(4) FX Sold*	(5) Net Position†
Canadian dollars (millions of C$)	158,058	149,893	901,521	934,328	−24,642
Japanese yen (billions of ¥)	59,620	54,591	471,248	481,227	−4,950
Swiss francs (millions of SF)	142,614	105,387	1,091,408	1,132,886	−4,251
British pounds (millions of £)	621,761	516,453	1,579,274	1,626,368	58,214
Euros (millions of €)	2,278,375	2,212,581	6,816,463	6,840,067	42,190

*Includes spot, future, and forward contracts.

†Net position = (Assets − Liabilities) + (FX bought − FX sold).

Source: Treasury Bulletin, June 2012, pp. 89–99. *www.treas.gov*

position—in each major currency). Foreign currency trading dominates direct portfolio investments. Even though the aggregate trading positions appear very large—for example, U.S. banks bought ¥471,248 billion—their overall or net exposure positions can be relatively small (e.g., the net position in yen was −¥4,950 billion).

An FIs overall FX exposure in any given currency can be measured by the net position **exposure**, which is measured in local currency and reported in column (5) of Table 19-3 as:

$$\begin{aligned}\text{Net exposure}_i &= (\text{FX assets}_i - \text{FX liabilities}_i) \\ &\quad + (\text{FX bought}_i - \text{FX sold}_i) \\ &= \text{Net foreign assets}_i + \text{Net FX bought}_i\end{aligned}$$

where

$$i = i\text{th currency.}$$

Clearly, an FI could match its foreign currency assets to its liabilities in a given currency and match buys and sells in its trading book in that foreign currency to reduce its foreign exchange net exposure to zero and thus avoid FX risk. It could also offset an imbalance in its foreign asset-liability portfolio by an opposing imbalance in its trading book so that its net exposure position in that currency would be zero. Further, financial holding companies can aggregate their foreign exchange exposure even more. Financial holding companies might have a commercial bank, an insurance company, and a pension fund all under one umbrella that allows them to reduce their net foreign exchange exposure across all units. For example, in March 2012, Citigroup held over $5.84 trillion in foreign exchange derivative securities off the balance sheet. Yet the company estimated the value at risk from its foreign exchange exposure was $145 million, or 0.001 percent.

Notice in Table 19-3 that U.S. banks had positive net FX exposures in two of the five major currencies in March 2012. A *positive* net exposure position implies a U.S. FI is overall **net long in a currency** (i.e., the FI has bought more foreign currency than it has sold) and faces the risk that the foreign currency will fall in value against the U.S. dollar, the domestic currency. A *negative* net exposure position implies that a U.S. FI is **net short in a foreign currency** (i.e., the FI has sold more foreign currency than it has purchased) and faces the risk that the foreign currency could rise in value against the dollar. Thus, failure to maintain a fully balanced position in any given currency exposes a U.S. FI to fluctuations in the FX rate of that currency against the dollar. Indeed, the greater the volatility of foreign exchange rates given any net exposure position, the greater the fluctuations in value of an FI's foreign exchange portfolio.

We have given the FX exposures for U.S. banks only, but most large nonbank FIs also have some FX exposure either through asset-liability holdings or currency trading. The absolute sizes of these exposures are smaller than those for major U.S. money center banks. The reasons for this are threefold: smaller asset sizes, prudent person

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concerns,[2] and regulations.[3] For example, U.S. pension funds invest approximately 5 percent of their asset portfolios in foreign securities, and U.S. life insurance companies generally hold less than 10 percent of their assets in foreign securities. Interestingly, U.S. FIs' holdings of overseas assets are less than those of FIs in Japan and Britain. For example, in Britain, pension funds have traditionally invested more than 20 percent of their funds in foreign assets.

Foreign Exchange Rate Volatility and FX Exposure

We can measure the potential size of an FI's FX exposure by analyzing the asset, liability, and currency trading mismatches on its balance sheet and the underlying volatility of exchange rate movements. Specifically, we can use the following equation:

Dollar loss/gain in currency i = [Net exposure in foreign currency i measured in U.S. dollars] × Shock (volatility) to the \$/foreign currency i exchange rate

The larger the FI's net exposure in a foreign currency and the larger the foreign currency's exchange rate volatility, the larger is the potential dollar loss or gain to an FI's earnings. As we discuss in more detail later in the chapter, the underlying causes of FX volatility reflect fluctuations in the demand for and supply of a country's currency. That is, conceptually, an FX rate is like the price of any good and will appreciate in value relative to other currencies when demand is high or supply is low and will depreciate in value when demand is low or supply is high. For example, during the summer of 2011, as the magnitude of the European crisis became apparent and the United States grappled with a looming debt default, Switzerland was one of the few countries with a safe and robust financial system and secure fiscal conditions. Investors bought Swiss francs as a safe haven currency. The purchases led to large appreciation of the currency: From September 2010 to September 2011, the Swiss franc appreciated by 14.8 percent against the U.S. dollar, 7.7 percent against the euro, 20.7 percent against the Japanese yen, and 14.8 percent against British pound (see Figure 19-2).

Concept Questions

1. How is the net foreign currency exposure of an FI measured?
2. If a bank is long in British pounds (£), does it gain or lose if the dollar appreciates in value against the pound?
3. A bank has £10 million in assets and £7 million in liabilities. It has also bought £52 million in foreign currency trading. What is its net exposure in pounds? (£55 million)

FOREIGN CURRENCY TRADING

The FX markets of the world have become one of the largest of all financial markets. Trading turnover averaged as high as \$4.7 trillion a day in recent years, 70 times the daily trading volume on the New York Stock Exchange. Of the \$4.7 trillion in average daily trading volume in the foreign exchange markets in 2011, \$1.57 trillion (33.5 percent) involved spot transactions, while \$3.13 trillion (66.5 percent) involved forward and other transactions. This compares to 1989 where average daily trading volume was \$590 billion; \$317 billion (53.7 percent) of which was spot foreign exchange transactions and \$273 billion (46.3 percent) forward and other foreign exchange transactions. The main reason for this increase in the use of forward relative to spot foreign exchange transactions is the increased ability to hedge foreign exchange risk with forward foreign exchange contracts (discussed later). Indeed, foreign exchange trading has continued to be one of the few sources of steady income for global banks during the late 2000s and early 2010s.

London continues to be the largest FX trading market, followed by New York and Tokyo.[4] Table 19-4 lists the top foreign currency traders as of June 2012. The top four banks

[2] Prudent person concerns are especially important for pension funds.

[3] For example, New York State restricts foreign asset holdings of New York-based life insurance companies to less than 10 percent of their assets.

[4] On a global basis, approximately 34 percent of trading in FX occurs in London, 17 percent in New York, and 6 percent in Tokyo. The remainder is spread throughout the world.

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TABLE 19-4 Top Currency Traders by Percent of Overall Volume

Rank	Name	Market Share
1	Deutsche Bank	14.57%
2	Citigroup	12.26
3	Barclays	10.95
4	UBS	10.48
5	HSBC	6.72
6	J.P. Morgan Chase	6.60
7	RBS	5.86
8	Credit Suisse	4.68
9	Morgan Stanley	3.52
10	Goldman Sachs	3.12

operating in these markets, Deutsche Bank (14.57 percent), Citigroup (12.26 percent), Barclays (10.95 percent), and UBS (10.48 percent), comprise almost half of all foreign currency trading. Foreign exchange trading has been called the fairest market in the world because of its immense volume and the fact that no single institution can control the market's direction. Although professionals refer to global foreign exchange trading as a market, it is not really one in the traditional sense of the word. There is no central location where foreign exchange trading takes place. Moreover, the FX market is essentially a 24-hour market, moving among Tokyo, London, and New York throughout the day. Therefore, fluctuations in exchange rates and thus FX trading risk exposure continues into the night even when other FI operations are closed. This clearly adds to the risk from holding mismatched FX positions. Most of the volume is traded among the top international banks, which process currency transactions for everyone from large corporations to governments around the world. Online foreign exchange trading is increasing. Electronic foreign exchange trading volume tops 60 percent of overall global foreign exchange trading. The transnational nature of the electronic exchange of funds makes secure, Internet-based trading an ideal platform. Online trading portals—terminals where currency transactions are being executed—are a low-cost way of conducting spot and forward foreign exchange transactions.

FX Trading Activities

An FI's position in the FX markets generally reflects four trading activities:

1. The purchase and sale of foreign currencies to allow customers to partake in and complete international commercial trade transactions.
2. The purchase and sale of foreign currencies to allow customers (or the FI itself) to take positions in foreign real and financial investments.
3. The purchase and sale of foreign currencies for hedging purposes to offset customer (or FI) exposure in any given currency.
4. The purchase and sale of foreign currencies for speculative purposes through forecasting or anticipating future movements in FX rates.

In the first two activities, the FI normally acts as an *agent of* its customers for a fee but does not assume the FX risk itself. Citigroup is the dominant supplier of FX to retail customers in the United States and worldwide. As of 2012, the aggregate value of Citigroup's principal amount of foreign exchange contracts totaled $5.8 trillion. In the third activity, the FI acts defensively as a hedger to reduce FX exposure. For example, an FI may take a short (sell) position in the foreign exchange of a country to offset a long (buy) position in the foreign exchange of that same country. Thus, FX risk exposure essentially relates to **open positions** taken as a principal by the FI for speculative purposes, the fourth activity. An FI usually creates an open position by taking an unhedged position in a foreign currency in its FX trading with other FIs.

The Federal Reserve estimates that 200 FIs are active market makers in foreign currencies in the U.S. foreign exchange market with about 25 commercial and investment banks making a market in the five major currencies. FIs can make speculative trades directly with other FIs or arrange them through specialist FX brokers. The Federal Reserve Bank of New York estimates that approximately 45 percent of speculative or open position trades are accomplished through specialized brokers who receive a fee for arranging trades between FIs. Speculative trades can be instituted through a variety of FX instruments.

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TABLE 19-5 Foreign Exchange Trading Income of Major U.S. Banks (in millions of dollars)

	1995	2000	2005	2008	2009	2011
Bank of America	$303.0	$524.0	$769.8	$1,772.8	$833.2	$1,391.3
Bank of New York Mellon	42.0	261.0	266.0	1,181.5	832.3	727.0
Citigroup	1,053.0	1,243.0	2,519.0	2,590.0	1,855.0	1,871.0
Fifth Third	0.0	0.0	51.7	105.6	76.3	63.4
HSBC North America	0.0	6.5	133.9	643.8	915.2	164.7
J.P. Morgan Chase	253.0	1,456.0	997.0	1,844.0	2,541.0	1,043.0
KeyCorp	8.0	19.6	38.6	63.0	47.1	42.9
Northern Trust	54.8	142.0	180.2	616.2	445.7	382.2
PNC	4.5	22.3	38.3	74.0	79.7	89.2
State Street B&TC	140.7	386.5	468.5	1,066.4	679.9	685.1
Suntrust	0.0	16.9	5.7	35.7	37.6	44.2
U.S. Bancorp	7.3	22.4	30.9	68.2	67.0	76.0
Wells Fargo	14.7	191.9	350.0	392.4	516.2	524.0
Total	1,881.0	$4,292.1	$5,849.6	$10,453 .6	$8,926.2	$7,104.0

Source: FDIC, *Statistics on Depository Institutions,* various dates. *www.fdic.gov*

Spot currency trades are the most common, with FIs seeking to make a profit on the difference between buy and sell prices (i.e., on movements in the bid-ask prices over time). However, FIs can also take speculative positions in foreign exchange forward contracts, futures, and options.

Most profits or losses on foreign trading come from taking an open position or speculating in currencies. Revenues from market making—the bid-ask spread—or from acting as agents for retail or wholesale customers generally provide only a secondary or supplementary revenue source. Note the trading income from FX trading for some large U.S. banks in Table 19-5. The dominant FX trading banks in the United States are Citigroup, Bank of America, and J.P. Morgan Chase. As can be seen, total trading income grew steadily in the years prior to the financial crises. For just these 13 FIs, income from trading activities increased from $1,881.0 million in 1995 to $10,453.6 million in 2008, a 456 percent increase over the 13-year period. Income from foreign exchange trading activities, however, fell during the financial crisis, to $8,923.2 million in 2009, and had yet to recover by 2011, falling further to $7,104.0 million.

Concept Questions

1. What are the four major FX trading activities?
2. In which trades do FIs normally act as agents, and in which trades as principals?
3. What is the source of most profits or losses on foreign exchange trading? What foreign currency activities provide a secondary source of revenue?

FOREIGN ASSET AND LIABILITY POSITIONS

The second dimension of an FI's FX exposure results from any mismatches between its foreign financial asset and foreign financial liability portfolios. As discussed earlier, an

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FI is long a foreign currency if its assets in that currency exceed its liabilities, while it is short a foreign currency if its liabilities in that currency exceed its assets. Foreign financial assets might include Swiss franc-denominated bonds, British pound-denominated gilt-edged securities, or peso-denominated Mexican bonds. Foreign financial liabilities might include issuing British pound CDs or a yen-denominated bond in the Euromarkets to raise yen funds. The globalization of financial markets has created an enormous range of possibilities for raising funds in currencies other than the home currency. This is important for FIs that wish to not only diversify their sources and uses of funds but also exploit imperfections in foreign banking markets that create opportunities for higher returns on assets or lower funding costs.

The Return and Risk of Foreign Investments

This section discusses the extra dimensions of return and risk from adding foreign currency assets and liabilities to an FI's portfolio. Like domestic assets and liabilities, profits (returns) result from the difference between contractual income from and costs paid on a security. With foreign assets and liabilities, however, profits (returns) are also affected by changes in foreign exchange rates.

Example 19.1 Calculating the Return on Foreign Exchange Transactions of a U.S. FI

Suppose that an FI has the following assets and liabilities:

Assets	Liabilities
$100 million U.S. loans (1 year) in dollars	$200 million U.S. CDs (1 year) in dollars
$100 million equivalent U.K. loans (1 year) (loans made in pounds)	

The U.S. FI is raising all of its $200 million liabilities in dollars (one-year CDs) but investing 50 percent in U.S. dollar assets (one-year maturity loans) and 50 percent in U.K. pound assets (one-year maturity loans).[5] In this example, the FI has matched the duration of its assets and liabilities ($D_A = D_L = 1$ year), but has mismatched the currency composition of its asset and liability portfolios. Suppose the promised one-year U.S. CD rate is 8 percent, to be paid in dollars at the end of the year, and that one-year, default risk-free loans in the United States are yielding 9 percent. The FI would have a positive spread of 1 percent from investing domestically. Suppose, however, that default risk-free, one-year loans are yielding 15 percent in the United Kingdom.

To invest in the United Kingdom, the FI decides to take 50 percent of its $200 million in funds and make one-year maturity U.K. pound loans while keeping 50 percent of its funds to make U.S. dollar loans. To invest $100 million (of the $200 million in CDs issued) in one-year loans in the United Kingdom, the U.S. FI engages in the following transactions [illustrated in panel (a) of Figure 19-3].

1. At the beginning of the year, sells $100 million for pounds on the spot currency markets. If the exchange rate is $1.60 to £1, this translates into $100 million/1.6 = £62.5 million.
2. Takes the £62.5 million and makes one-year U.K. loans at a 15 percent interest rate.
3. At the end of the year, pound revenue from these loans will be £62.5(1.15) = £71.875 million.
4. Repatriates these funds back to the United States at the end of the year. That is, the U.S. FI sells the £71.875 million in the foreign exchange market at the spot exchange rate that exists at that time, the end of the year spot rate.

Suppose the spot foreign exchange rate has not changed over the year; it remains fixed at $1.60/£1. Then the dollar proceeds from the U.K. investment will be:

$$£71.875 \text{ million} \times \$1.60/£1 = \$115 \text{ million}$$

or, as a return,

$$\frac{\$115 \text{ million} - \$100 \text{ million}}{\$100 \text{ million}} = 15\%$$

Given this, the weighted return on the bank's portfolio of investments would be:

$$(0.5)(0.09) + (0.5)(0.15) = 0.12 \text{ or } 12\%$$

This exceeds the cost of the FI's CDs by 4 percent (12% − 8%).

Suppose, however, that at the end of the year the British pound falls in value relative to the dollar, or the

[5] For simplicity, we ignore the leverage or net worth aspects of the FI's portfolio.

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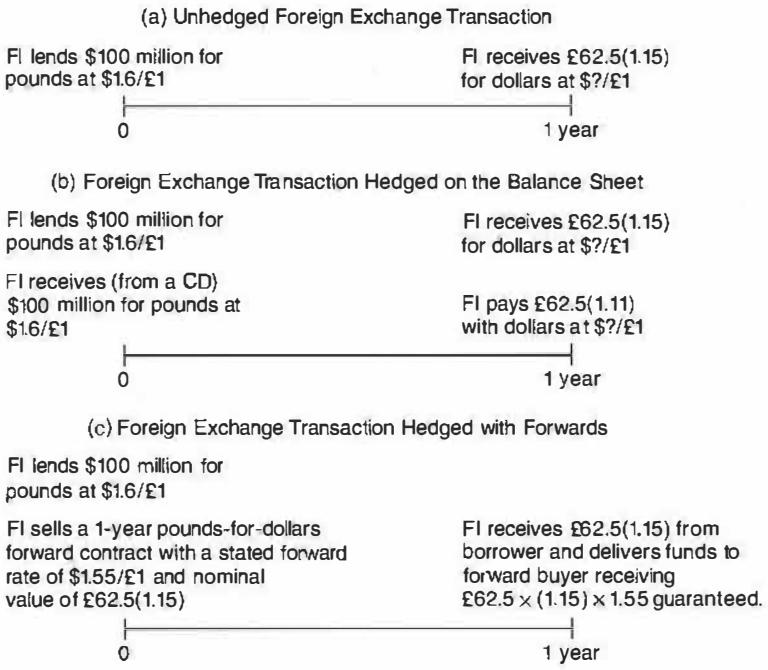

FIGURE 19-3 Time line for a foreign exchange transaction.

U.S. dollar appreciates in value relative to the pound. The return on the U.K. loans could be far less than 15 percent even in the absence of interest rate or credit risk. For example, suppose the exchange rate falls from $1.60/£1 at the beginning of the year to $1.45/£1 at the end of the year when the FI needs to repatriate the principal and interest on the loan. At an exchange rate of $1.45/£1, the pound loan revenues at the end of the year translate into:

$$£71.875 \text{ million} \times \$1.45/£1 = \$104.22 \text{ million}$$

or as a return on the original dollar investment of:

$$\frac{\$104.22 - \$100}{\$100} = 0.0422 = 4.22\%$$

The weighted return on the FI's asset portfolio would be:

$$(0.5)(0.09) + (0.5)(0.0422) = 0.0661 = 6.61\%$$

In this case, the FI actually has a loss or has a negative interest margin (6.61% − 8% = −1.39%) on its balance sheet investments.

The reason for the loss is that the depreciation of the pound from $1.60 to $1.45 has offset the attractive high yield on British pound loans relative to domestic U.S. loans. If the pound had instead appreciated (risen in value) against the dollar over the year—say, to $1.70/£1—then the U.S. FI would have generated a dollar return from its U.K. loans of:

$$£71.875 \times \$1.70 = \$122.188 \text{ million}$$

or a percentage return of 22.188 percent. Then the U.S. FI would receive a double benefit from investing in the United Kingdom: a high yield on the domestic British loans plus an appreciation in pounds over the one-year investment period.

Risk and Hedging

Since a manager cannot know in advance what the pound/dollar spot exchange rate will be at the end of the year, a portfolio imbalance or investment strategy in which the FI is *net long* $100 million in pounds (or £62.5 million) is risky. As we discussed, the British loans would generate a return of 22.188 percent if the pound appreciated from $1.60/£1 to $1.70/£1, but would produce a return of only 4.22 percent if the pound depreciated in value against the dollar to $1.45/£1.

In principle, an FI manager can better control the scale of its FX exposure in two major ways: on-balance-sheet hedging and off-balance-sheet hedging. On-balance-sheet hedging involves making changes in the on-balance-sheet assets and liabilities to protect FI profits from FX risk. Off-balance-sheet hedging involves no on-balance-sheet changes, but rather involves taking a position in forward or other derivative securities to hedge FX risk.

On-Balance-Sheet Hedging

The following example illustrates how an FI manager can control FX exposure by making changes on the balance sheet.

Example 19.2 Hedging on the Balance Sheet

Suppose that instead of funding the $100 million investment in 15 percent British loans with U.S. CDs, the FI manager funds the British loans with $100 million equivalent

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one-year pound CDs at a rate of 11 percent [as illustrated in panel (b) of Figure 19-3] Now the balance sheet of the bank would look like this:

Assets	Liabilities
$100 million U.S. loans (9%)	$100 million U.S. CDs (8%)
$100 million U.K. loans (15%) (loans made in pounds)	$100 million U.K. CDs (11%) (deposits raised in pounds)

In this situation, the FI has both a matched maturity and currency foreign asset–liability book. We might now consider the FI's profitability or spread between the return on assets and the cost of funds under two scenarios: first, when the pound depreciates in value against the dollar over the year from $1 .60/£1 to $1.45/£1 and second, when the pound appreciates in value over the year from $1.60/£1 to $1.70/£1.

The Depreciating Pound

When the pound falls in value to $1.45/£1, the return on the British loan portfolio is 4.22 percent. Consider now what happens to the cost of $100 million in pound liabilities in dollar terms:

1. At the beginning of the year, the FI borrows $100 million equivalent in pound CDs for one year at a promised interest rate of 11 percent. At an exchange rate of $1.60£, this is a pound equivalent amount of borrowing of $100 million/1.6 = £62.5 million.
2. At the end of the year, the bank has to pay back the pound CD holders their principal and interest, £62.5 million(1.11) = £69.375 million.
3. If the pound depreciates to $1.45/£1 over the year, the repayment in dollar terms would be £69.375 million × $1.45/£1 = $100.59 million, or a dollar cost of funds of 0.59 percent.

Thus, at the end of the year the following occurs:

Average return on assets:

$$(0.5)(0.09) + (0.5)(0.0422) = 0.0661 = 6.61\%$$

U.S. asset return + U.K. asset return = Overall return

Average cost of funds:

$$(0.5)(0.08) + (0.5)(0.0059) = 0.04295 = 4.295\%$$

U.S. cost of funds + U.K. cost of funds = Overall cost

Net return:

Average return on assets − Average cost of funds

$$6.61\% - 4.295\% = 2.315\%$$

The Appreciating Pound

When the pound appreciates over the year from $1.60/£1 to $1.70/£1, the return on British loans is equal to 22.188. Now consider the dollar cost of British one-year CDs at the end of the year when the U.S. FI has to pay the principal and interest to the CD holder:

$$£69.375 \text{ million} \times \$1.70/£1 = \$117.9375 \text{ million}$$

or a dollar cost of funds of 17.9375 percent. Thus, at the end of the year:

Average return on assets:

$$(0.5)(0.09) + (0.5)(0.22188) = 0.15594 \text{ or } 15.594\%$$

Average cost of funds:

$$(0.5)(0.08) + (0.5)(0.179375) = 0.12969 \text{ or } 12.969\%$$

Net return:

$$15.594 - 12.969 = 2.625\%$$

Note that even though the FI locked in a positive return when setting the net foreign exchange exposure on the balance sheet to zero, net return is still volatile. Thus, the FI is still exposed to foreign exchange risk. However, by directly matching its foreign asset and liability book, an FI can lock in a positive return or profit spread whichever direction exchange rates change over the investment period. For example, even if domestic U.S. banking is a relatively low profit activity (i.e., there is a low spread between the return on assets and the cost of funds), the FI could be quite profitable overall. Specifically, it could lock in a large positive spread—if it exists—between deposit rates and loan rates in foreign markets. In our example, a 4 percent positive spread existed between British one-year loan rates and deposit rates compared with only a 1 percent spread domestically.

Note that for such imbalances in domestic spreads and foreign spreads to continue over long periods of time, financial service firms would have to face significant barriers to entry in foreign markets. Specifically, if real and financial capital is free to move, FIs would increasingly withdraw from the U.S. market and reorient their operations toward the United Kingdom. Reduced competition

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would widen loan deposit interest spreads in the United States, and increased competition would contract U.K. spreads, until the profit opportunities from foreign activities disappears.[6]

Hedging with Forwards

Instead of matching its $100 million foreign asset position with $100 million of foreign liabilities, the FI might have chosen to remain unhedged on the balance sheet. As a lower-cost alternative, it could hedge by taking a position in the forward market for foreign currencies—for example, the one-year forward market for selling pounds for dollars.[7] However, here we introduce them to show how they can insulate the FX risk of the FI in our example. Any forward position taken would not appear on the balance sheet. It would appear as a contingent off-balance-sheet claim, which we describe as an item below the bottom line. The role of the forward FX contract is to offset the uncertainty regarding the future spot rate on pounds at the end of the one-year investment horizon. Instead of waiting until the end of the year to transfer pounds back into dollars at an unknown spot rate, the FI can enter into a contract to sell forward its *expected* principal and interest earnings on the loan, at today's known **forward exchange rate** for dollars/pounds, with delivery of pound funds to the buyer of the forward contract taking place at the end of the year. Essentially, by selling the expected proceeds on the pound loan forward, at a known (forward FX) exchange rate today, the FI removes the future spot exchange rate uncertainty and thus the uncertainty relating to investment returns on the British loan.

Example 19.3 Hedging with Forwards

Consider the following transactional steps when the FI hedges its FX risk immediately by selling its expected one-year pound loan proceeds in the forward FX market [illustrated in panel (c) of Figure 19-3].

1. The U.S. FI sells $100 million for pounds at the *spot* exchange rate *today* and receives $100 million/1.6 = £62.5 million.
2. The FI then immediately lends the £62.5 million to a British customer at 15 percent for one year.
3. The FI also sells the expected principal and interest proceeds from the pound loan forward for dollars at today's forward rate for one-year delivery. Let the current forward one-year exchange rate between dollars and pounds stand at $1.55/£1, or at a 5 cent discount to the spot pound; as a percentage discount:

   $$(\$1.55 - \$1.60)/\$1.6 = -3.125\%$$

   This means that the forward buyer of pounds promises to pay:

   $$£62.5 \text{ million } (1.15) \times \$1.55/£1 = £71.875 \text{ million} \times \$1.55/£1 = \$111.406 \text{ million}$$

   to the FI (the forward seller) in one year when the FI delivers the £71.875 million proceeds of the loan to the forward buyer.
4. In one year, the British borrower repays the loan to the FI plus interest in pounds (£71.875 million).
5. The FI delivers the £71.875 million to the buyer of the one-year forward contract and receives the promised $111.406 million.

[6] In the background of the previous example was the implicit assumption that the FI was also matching the durations of its foreign assets and liabilities. In our example, it was issuing one-year duration pound CDs to fund one-year duration pound loans. Suppose instead that it still had a matched book in size ($100 million) but funded the one-year 15 percent British loans with three-month 11 percent pound CDs.

$$D_{£A} - D_{£L} = 1 - 0.25 = 0.75 \text{ year}$$

Thus, pound assets have a longer duration than do pound liabilities.

If British interest rates were to change over the year, the market value of pound assets would change by more than the market value of pound liabilities. More importantly, the FI would no longer be locking in a fixed return by matching in the size of its foreign currency book since it would have to take into account its potential exposure to capital gains and losses on its pound assets and liabilities due to shocks to British interest rates. In essence, an FI is hedged against both foreign exchange rate risk and foreign interest rate risk only if it matches both the size and the durations of its foreign assets and liabilities in a specific currency.

[7] An FI could also hedge its on-balance-sheet FX risk by taking off-balance-sheet positions in futures, swaps, and options on foreign currencies.

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Barring the pound borrower's default on the loan or the forward buyer's reneging on the forward contract, the FI knows from the very beginning of the investment period that it has locked in a guaranteed return on the British loan of

$$\frac{\$111.406 - \$100}{\$100} = 0.11406 = 11.406\%$$

Specifically, this return is fully hedged against any dollar/pound exchange rate changes over the one-year holding period of the loan investment. Given this return on British loans, *the overall expected return* on the FI's asset portfolio is:

$$(0.5)(0.09) + (0.5)(0.11406) = 0.10203 \text{ or } 10.203\%$$

Since the cost of funds for the FI's $200 million U.S. CDs is an assumed 8 percent, it has been able to lock in a risk-free return spread over the year of 2.203 percent regardless of spot exchange rate fluctuations between the initial foreign (loan) investment and repatriation of the foreign loan proceeds one year later.

In the preceding example, it is profitable for the FI to increasingly drop domestic U.S. loans and invest in hedged foreign U.K. loans, since the hedged dollar return on foreign loans of 11.406 percent is so much higher than 9 percent domestic loans. As the FI seeks to invest more in British loans, it needs to buy more spot pounds. This drives up the spot price of pounds in dollar terms to more than $1.60/£1. In addition, the FI would need to sell more pounds forward (the proceeds of these pound loans) for dollars, driving the forward rate to below $1.55/£1. The outcome would widen the dollar forward-spot exchange rate spread on pounds, making forward hedged pound investments less attractive than before. This process would continue until the U.S. cost of FI funds just equals the forward hedged return on British loans. That is, the FI could make no further profits by borrowing in U.S. dollars and making forward contract-hedged investments in U.K. loans (see also the discussion below on the interest rate parity theorem).

Multicurrency Foreign Asset–Liability Positions

So far, we have used a one-currency example of a matched or mismatched foreign asset–liability portfolio. Many FIs, including banks, mutual funds, and pension funds, hold multicurrency asset–liability positions. As for multicurrency trading portfolios, diversification across many asset and liability markets can potentially reduce the risk of portfolio returns and the cost of funds. To the extent that domestic and foreign interest rates or stock returns for equities do not move closely together over time, potential gains from asset–liability portfolio diversification can offset the risk of mismatching individual currency asset-liability positions.

Theoretically speaking, the one-period nominal interest rate (r_i) on fixed-income securities in any particular country has two major components. First, the **real interest rate** reflects underlying real sector demand and supply for funds in that currency. Second, the *expected inflation rate* reflects an extra amount of interest lenders demand from borrowers to compensate the lenders for the erosion in the principal (or real) value of the funds they lend due to inflation in goods prices expected over the period of the loan. Formally:[8]

$$r_i = rr_i + i_i^e$$

where

r_i = Nominal interest rate in country i

rr_i = Real interest rate in country i

i_i^e = Expected one-period inflation rate in country i

If real savings and investment demand and supply pressures, as well as inflationary expectations, are closely linked or economic integration across countries exists, we expect to find that nominal interest rates are highly correlated across financial markets. For example, if, as the result of a strong demand for investment funds, German real interest rates rise, there may be a capital outflow from other countries toward Germany. This may lead to rising real and nominal interest rates in other countries as policymakers and borrowers try to mitigate the size of their capital outflows. On the other hand, if the world capital market is not very well integrated, quite significant nominal and real interest deviations may exist before equilibrating international flows of funds materialize. Foreign asset or liability returns are likely to be relatively weakly correlated and significant diversification opportunities exist.

[8] This equation is often called the *Fisher equation* after the economist who first publicized this hypothesized relationship among nominal rates, real rates, and expected inflation. As shown, we ignore the small cross-product term between the real rate and the expected inflation rate.

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TABLE 19-6 Correlation of Returns on Stock Markets before and during the Financial Crisis

Panel A: Pre-crisis, December 19, 2000–September 12, 2008				
	United States	**United Kingdom**	**Japan**	**Hong Kong**
United States	1.000	0.456	0.132	0.135
United Kingdom	0.456	1.000	0.294	0.302
Japan	0.131	0.294	1.000	0.506
Hong Kong	0.135	0.302	0.506	1.000
Australia	0.085	0.281	0.488	0.500
Brazil	0.553	0.354	0.132	0.174
Canada	0.663	0.460	0.176	0.220
Germany	0.538	0.778	0.283	0.285
Panel B: Crisis, September 5, 2008–December 15, 2010				
	United States	**United Kingdom**	**Japan**	**Hong Kong**
United States	1.000	0.631	0.138	0.216
United Kingdom	0.631	1.000	0.273	0.351
Japan	0.138	0.273	1.000	0.573
Hong Kong	0.216	0.351	0.573	1.000
Australia	0.160	0.340	0.640	0.611
Brazil	0.702	0.514	0.112	0.301
Canada	0.777	0.574	0.213	0.302
Germany	0.663	0.865	0.271	0.327

Source: R. Horvath and P. Poldauf, "International Stock Market Comovements: What Happened During the Financial Crisis?" *Global Economy Journal*, March 2012.

Table 19-6 lists the correlations among the returns in major stock indices before and during the financial crisis. Looking at correlations between foreign stock market returns and U.S. stock market returns, you can see that all are positive. Further, relative to the pre-crisis period, stock market return correlations increased during the financial crisis. In the pre-crisis period, correlations across markets vary from a high of 0.778 between the United Kingdom and Germany to a low of 0.131 between the United States and Japan. In the crisis period, correlations across markets vary from a high of 0.865 between the United Kingdom and Germany to a low of 0.112 between Japan and Brazil.[9]

Concept Questions

1. The cost of one-year U.S. dollar CDs is 8 percent, one-year U.S. dollar loans yield 10 percent, and U.K. pound loans yield 15 percent. The dollar/pound spot

[9] From the Fisher relationship, high correlations may be due to high correlations of real interest rates over time and/or inflation expectations.

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exchange rate is $1.50/£1, and the one-year forward exchange rate is $1.48/£1. Are one-year U.S. dollar loans more or less attractive than U.K. pound loans?

2. What are two ways an FI manager can control FX exposure?

INTERACTION OF INTEREST RATES, INFLATION, AND EXCHANGE RATES

As global financial markets have become increasingly interlinked, so have interest rates, inflation, and foreign exchange rates. For example, higher domestic interest rates may attract foreign financial investment and impact the value of the domestic currency. In this section, we look at the effect that inflation in one country has on its foreign currency exchange rates—purchasing power parity (PPP). We also examine the links between domestic and foreign interest rates and spot and forward foreign exchange rates—interest rate parity (IRP).

Purchasing Power Parity

One factor affecting a country's foreign currency exchange rate with another country is the relative inflation rate in each country (which, as shown below, is directly related to the relative interest rates in these countries). Specifically:

$$r_{US} = i_{US} + rr_{US}$$

and

$$r_S = i_S + rr_S$$

where

r_{US} = Interest rate in the United States

r_S = Interest rate in Switzerland (or another foreign country)

i_{US} = Inflation rate in the United States

i_S = Inflation rate in Switzerland (or another foreign country)

rr_{US} = Real rate of interest in the United States

rr_S = Real rate of interest in Switzerland (or another foreign country)

Assuming real rates of interest (or rates of time preference) are equal across countries:

$$rr_{US} = rr_S$$

Then

$$r_{US} - r_S = i_{US} - i_S$$

The (nominal) interest rate spread between the United States and Switzerland reflects the difference in inflation rates between the two countries.

As relative inflation rates (and interest rates) change, foreign currency exchange rates that are not constrained by government regulation should also adjust to account for relative differences in the price levels (inflation rates) between the two countries. One theory that explains how this adjustment takes place is the theory of **purchasing power parity (PPP)**. According to PPP, foreign currency exchange rates between two countries adjust to reflect changes in each country's price levels (or inflation rates and, implicitly, interest rates) as consumers and importers switch their demands for goods from relatively high inflation (interest) rate countries to low inflation (interest) rate countries. Specifically, the PPP theorem states that the change in the exchange rate between two countries' currencies is proportional to the difference in the inflation rates in the two countries. That is:

$$i_{Domestic} - i_{Foreign} = \Delta S_{Domestic/Foreign} / S_{Domestic/Foreign}$$

Where

$S_{Domestic/Foreign}$ = Spot exchange rate of the domestic currency for the foreign currency (e.g., U.S. dollars for Swiss francs)

$\Delta S_{Domestic/Foreign}$ = Change in the one-period spot foreign exchange rate

Thus, according to PPP, the most important factor determining exchange rates is the fact that in open economies, differences in prices (and, by implication, price level changes with inflation) drive trade flows and thus demand for and supplies of currencies.

Example 19.4 Application of Purchasing Power Parity

Suppose that the current spot exchange rate of U.S. dollars for Russian rubles, $S_{US/R}$, is 0.17 (i.e., 0.17 dollar, or 17 cents, can be received for 1 ruble). The price of Russian-produced goods increases by 10 percent (i.e., inflation in Russia, i_R, is 10 percent), and the U.S. price index increases by 4 percent (i.e., inflation in the United States, i_{US}, is 4 percent). According to PPP, the 10 percent rise in the price of Russian goods relative to the 4 percent rise in the

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price of U.S. goods results in a depreciation of the Russian ruble (by 6 percent). Specifically, the exchange rate of Russian rubles to U.S. dollars should fall, so that:[10]

$$\text{U.S. inflation rate} - \text{Russian inflation rate} = \frac{\text{Change in spot exchange rate of U.S. dollars for Russian rubles}}{\text{Initial spot exchange rate of U.S. dollars for Russian rubles}}$$

or

$$i_{US} - i_R = \Delta S_{US/R} \,/\, S_{US/R}$$

Plugging in the inflation and exchange rates, we get:

$$0.04 - 0.10 = \Delta S_{US/R} \,/\, S_{US/R} = \Delta S_{US/R} \,/\, 0.17$$

or

$$-0.06 = \Delta S_{US/R} \,/\, 0.17$$

and

$$\Delta S_{US/R} = 0.06 \times 0.17 = -0.0102$$

Thus, it costs 1.02 cents less to receive a ruble (i.e, 1 ruble costs 15.98 cents: 17 cents − 1.02 cents), or 0.1598 of $1 can be received for 1 ruble. The Russian ruble depreciates in value by 6 percent against the U.S. dollar as a result of its higher inflation rate.[11]

Interest Rate Parity Theorem

We discussed above that foreign exchange spot market risk can be reduced by entering into forward foreign exchange contracts. In general, spot rates and forward rates for a given currency differ. For example, the spot exchange rate between the British pound and the U.S. dollar was 1.5591 on July 4, 2012, meaning that 1 pound could be exchanged on that day for 1.5591 U.S. dollars. The three-month forward rate between the two currencies, however, was 1.5590 on July 4, 2012. This forward exchange rate is determined by the spot exchange rate and the interest rate differential between the two countries. The specific relationship that links spot exchange rates, interest rates, and forward exchange rates is described as the **Interest rate parity theorem** (IRPT).

Intuitively, the IRPT implies that by hedging in the forward exchange rate market, an investor realizes the same returns whether investing domestically or in a foreign country. This is a so-called no-arbitrage relationship in the sense that the investor cannot make a risk-free return by taking offsetting positions in the domestic and foreign markets. That is, the hedged dollar return on foreign investments just equals the return on domestic investments. The eventual equality between the cost of domestic funds and the hedged return on foreign assets, or the IRPT, can be expressed as:

$$1 + r^D_{ust} = \frac{1}{S_t} \times \left[1 + r^L_{ukt}\right] \times F_t$$

Rate on U.S. investment = Hedged return on foreign (U.K.) investment

where

$1 + r^D_{ust}$ = 1 plus the interest rate on U.S. CDs for the FI at time t

S_t = $/£ spot exchange rate at time t

$1 + r^L_{ukt}$ = 1 plus the interest rate on UK CDs at time t

F_t = $/£ forward exchange at time t

Example 19.5 An Application of Interest Rate Parity Theorem

Suppose r^D_{ust} = 8 percent and r^L_{ukt} = 11 percent, as in our preceding example. As the FI moves into more British CDs, suppose the spot exchange rate for buying pounds rises from $1.60/£1 to $1.63/£1. In equilibrium, the forward exchange rate would have to fall to $1.5859/£1 to eliminate completely the attractiveness of British investments to the U.S. FI manager. That is:

$$(1.08) = \left(\frac{1}{1.63}\right)[1.11](1.5859)$$

This is a *no-arbitrage* relationship in the sense that the hedged dollar return on foreign investments just equals the FI's dollar cost of domestic CDs. Rearranging, the IRPT can be expressed as:

$$\frac{r^D_{ust} - r^L_{ukt}}{1 + r^L_{ukt}} \simeq \frac{F_t - S_t}{S_t}$$

$$\frac{0.08 - 0.11}{1.11} \simeq \frac{1.5859 - 1.63}{1.63}$$

$$-0.0270 \simeq -0.0270$$

[10] This is the relative version of the PPP theorem. There are other versions of the theory (such as absolute PPP and the law of one price). However, the version show n here is the one most commonly used.

[11] A 6 percent fall in the ruble's value translates into a new exchange rate of 0.1598 dollar per ruble if the original exchange rate between dollars and rubles was 0.17.

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That is, the discounted spread between domestic and foreign interest rates is approximately equal to (≈) the percentage spread between forward and spot exchange rates.

Suppose that in the preceding example, the annual rate on U.S. time deposits is 8.1 percent (rather than 8 percent). In this case, it would be profitable for the investor to put excess funds in the U.S. rather than the UK deposits. The arbitrage opportunity that exists results in a flow of funds out of UK time deposits into U.S. time deposits. According to the IRPT, this flow of funds would quickly drive up the U.S. dollar-British pound exchange rate until the potential profit opportunities from U.S. deposits are eliminated. The implication of IRPT is that in a competitive market for deposits, loans, and foreign exchange, the potential profit opportunities from overseas investment for the FI manager are likely to be small and fleeting. Long-term violations of IRPT are likely to occur only if there are major imperfections in international deposit loan, and other financial markets, including barriers to cross-border financial flows.

Concept Questions

1. What is purchasing power parity?
2. What is the interest rate parity condition? How does it relate to the existence or non-existence of arbitrage opportunities?

SUMMARY

This chapter analyzed the sources of FX risk faced by FI managers. Such risks arise through mismatching foreign currency trading and/or foreign asset–liability positions in individual currencies. While such mismatches can be profitable if FX forecasts prove correct, unexpected outcomes and volatility can impose significant losses on an FI. They threaten its profitability and, ultimately, its solvency in a fashion similar to interest rate and liquidity risks. This chapter discussed possible ways to mitigate such risks, including direct hedging through matched foreign asset–liability books, hedging through forward contracts, and hedging through foreign asset and liability portfolio diversification.

INTEGRATED MINI CASE

Foreign Exchange Risk Exposure

Suppose that a U.S. FI has the following assets and liabilities:

Assets	Liabilities
$500 million U.S. loans (one year) in dollars	$1,000 million U.S. CDs (one year) in dollars
$300 million equivalent U.K. loans (one year) (loans made in pounds)	
$200 million equivalent Turkish loans (one year) (loans made in Turkish lira)	

The promised one-year U.S. CD rate is 4 percent, to be paid in dollars at the end of the year; the one-year, default risk-free loans in the United States are yielding 6 percent; default risk-free one-year loans are yielding 8 percent in the United Kingdom; and default risk-free one-year loans are yielding 10 percent in Turkey. The exchange rate of dollars for pounds at the beginning of the year is $1.6/£1, and the exchange rate of dollars for Turkish lira at the beginning of the year is $0.5533/TRY1.

1. Calculate the dollar proceeds from the FI's loan portfolio at the end of the year, the return on the FI's loan portfolio, and the net interest margin for the FI if the spot foreign exchange rate has not changed over the year.
2. Calculate the dollar proceeds from the FI's loan portfolio at the end of the year, the return on the FI's loan portfolio, and the net interest margin for the FI if the pound spot foreign exchange rate falls to $1.45/£1 and the lira spot foreign exchange rate falls to $0.52/TRY1 over the year.
3. Calculate the dollar proceeds from the FI's loan portfolio at the end of the year, the return on the FI's loan portfolio, and the net interest margin for the FI if the pound spot foreign exchange rate rises to $1.70/£1 and the lira spot foreign exchange rate rises to $0.58/TRY1 over the year.

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4. Suppose that instead of funding the $300 million investment in 8 percent British loans with U.S. CDs, the FI manager funds the British loans with $300 million equivalent one-year pound CDs at a rate of 5 percent and that instead of funding the $200 million investment in 10 percent Turkish loans with U.S. CDs, the FI manager funds the Turkish loans with $200 million equivalent one-year Turkish lira CDs at a rate of 6 percent. What will the FI's balance sheet look like after these changes have been made?

5. Calculate the return on the FI's loan portfolio, the average cost of funds, and the net interest margin for the FI if the pound spot foreign exchange rate falls to $1.45/£1 and the lira spot foreign exchange rate falls to $0.52/TRY1 over the year.

6. Calculate the return on the FI's loan portfolio, the average cost of funds, and the net interest margin for the FI if the pound spot foreign exchange rate rises to $1.70/ £1 and the lira spot foreign exchange rate falls to $0.58/TRY1 over the year.

7. Suppose that instead of funding the $300 million investment in 8 percent British loans with CDs issued in the United Kingdom, the FI manager hedges the foreign exchange risk on the British loans by immediately selling its expected one-year pound loan proceeds in the forward FX market. The current forward one-year exchange rate between dollars and pounds is $1.53/£1. Additionally, instead of funding the $200 million investment in 10 percent Turkish loans with CDs issued in the Turkey, the FI manager hedges the foreign exchange risk on the Turkish loans by immediately selling its expected one-year lira loan proceeds in the forward FX market. The current forward one-year exchange rate between dollars and Turkish lira is $0.5486/TRY1. Calculate the return on the FI's investment portfolio (including the hedge) and the net interest margin for the FI over the year.

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Corporate Bonds

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Learning Objectives

After completing this reading you should be able to:

- Describe a bond indenture and explain the role of the corporate trustee in a bond indenture.
- Explain a bond's maturity date and how it impacts bond retirements.
- Describe the main types of interest payment classifications.
- Describe zero-coupon bonds and explain the relationship between original-issue discount and reinvestment risk.
- Distinguish among the following security types relevant for corporate bonds: mortgage bonds, collateral trust bonds, equipment trust certificates, subordinated and convertible debenture bonds, and guaranteed bonds.
- Describe the mechanisms by which corporate bonds can be retired before maturity.
- Differentiate between credit default risk and credit spread risk.
- Describe event risk and explain what may cause it in corporate bonds.
- Define high-yield bonds, and describe types of high-yield bond issuers and some of the payment features unique to high yield bonds.
- Define and differentiate between an issuer default rate and a dollar default rate.
- Define recovery rates and describe the relationship between recovery rates and seniority.

Excerpt is Chapter 12 of The Handbook of Fixed Income Securities, *Eighth Edition, by Frank J. Fabozzi.*

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In its simplest form, a corporate bond is a debt instrument that obligates the issuer to pay a specified percentage of the bond's par value on designated dates (the coupon payments) and to repay the bond's par or principal value at maturity. Failure to pay the interest and/or principal when due (and to meet other of the debt's provisions) in accordance with the instrument's terms constitutes legal default, and court proceedings can be instituted to enforce the contract. Bondholders as creditors have a prior legal claim over common and preferred shareholders as to both the corporation's income and assets for cash flows due them and may have a prior claim over other creditors if liens and mortgages are involved. This legal priority does not insulate bondholders from financial loss. Indeed, bondholders are fully exposed to the firm's prospects as to the ability to generate cash-flow sufficient to pay its obligations.

Corporate bonds usually are issued in denominations of $1,000 and multiples thereof. In common usage, a corporate bond is assumed to have a par value of $1,000 unless otherwise explicitly specified. A security dealer who says that she has five bonds to sell means five bonds each of $1,000 principal amount. If the promised rate of interest (coupon rate) is 6%, the annual amount of interest on each bond is $60, and the semiannual interest is $30.

Although there are technical differences between bonds, notes, and debentures, we will use Wall Street convention and call fixed income debt by the general term—*bonds*.

THE CORPORATE TRUSTEE

The promises of corporate bond issuers and the rights of investors who buy them are set forth in great detail in contracts generally called *indentures.* If bondholders were handed the complete indenture, some may have trouble understanding the legalese and have even greater difficulty in determining from time to time if the corporate issuer is keeping all the promises made. Further, it may be practically difficult and expensive for any one bondholder to try to enforce the indenture if those promises are not being kept. These problems are solved in part by bringing in a *corporate trustee* as a third party to the contract. The indenture is made out to the corporate trustee as a representative of the interests of bondholders; that is, the trustee acts in a fiduciary capacity for investors who own the bond issue.

A corporate trustee is a bank or trust company with a corporate trust department and officers who are experts in performing the functions of a trustee. The corporate trustee must, at the time of issue, authenticate the bonds issued; that is, keep track of all the bonds sold, and make sure that they do not exceed the principal amount authorized by the indenture. It must obtain and address various certifications and requests from issuers, attorneys, and bondholders about compliance with the covenants of the indenture. These covenants are many and technical, and they must be watched during the entire period that a bond issue is outstanding. We will describe some of these covenants in subsequent pages.

It is very important that corporate trustees be competent and financially responsible. To this end, there is a federal statute known as the Trust Indenture Act that generally requires a corporate trustee for corporate bond offerings in the amount of more than $5 million sold in interstate commerce. The indenture must include adequate requirements for performance of the trustee's duties on behalf of bondholders; there must be no conflict between the trustee's interest as a trustee and any other interest it may have, especially if it is also a creditor of the issuer; and there must be provision for reports by the trustee to bondholders. If a corporate issuer has breached an indenture promise, such as not to borrow additional secured debt, or fails to pay interest or principal, the trustee may declare a default and take such action as may be necessary to protect the rights of bondholders.

However, it must be emphasized that the trustee is paid by the debt issuer and can only do what the indenture provides. The indenture may contain a clause stating that the trustee undertakes to perform such duties and only such duties as are specifically set forth in the indenture, and no implied covenants or obligations shall be read into the indenture against the trustee. Trustees often are not required to take actions such as monitoring corporate balance sheets to determine issuer covenant compliance, and in fact, indentures often expressly allow a trustee to rely upon certifications and opinions from the issuer and its attorneys. The trustee is generally not bound to make investigations into the facts surrounding documents delivered to it, but it may do so if it sees fit. Also, the trustee is usually under no obligation to exercise the rights or powers under the indenture at the request of bondholders unless it has been offered reasonable security or indemnity.

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The terms of bond issues set forth in bond indentures are always a compromise between the interests of the bond issuer and those of investors who buy bonds. The issuer always wants to pay the lowest possible rate of interest and wants its actions bound as little as possible with legal covenants. Bondholders want the highest possible interest rate, the best security, and a variety of covenants to restrict the issuer in one way or another. As we discuss the provisions of bond indentures, keep this opposition of interests in mind and see how compromises are worked out in practice.

SOME BOND FUNDAMENTALS

Bonds can be classified by a number of characteristics, which we will use for ease of organizing this section.

Bonds Classified by Issuer Type

The five broad categories of corporate bonds sold in the United States based on the type of issuer are public utilities, transportations, industrials, banks and finance companies, and international or Yankee issues. Finer breakdowns are often made by market participants to create homogeneous groupings. For example, public utilities are subdivided into telephone or communications, electric companies, gas distribution and transmission companies, and water companies. The transportation industry can be subdivided into airlines, railroads, and trucking companies. Like public utilities, transportation companies often have various degrees of regulation or control by state and/or federal government agencies. Industrials are a catchall class, but even here, finer degrees of distinction may be needed by analysts. The industrial grouping includes manufacturing and mining concerns, retailers, and service-related companies. Even the Yankee or international borrower sector can be more finely tuned. For example, one might classify the issuers into categories such as supranational borrowers (International Bank for Reconstruction and Development and the European Investment Bank), sovereign issuers (Canada, Australia, and the United Kingdom), and foreign municipalities and agencies.

Corporate Debt Maturity

A bond's maturity is the date on which the issuer's obligation to satisfy the terms of the indenture is fulfilled. On that date, the principal is repaid with any premium and accrued interest that may be due. However, as we shall see later when discussing debt redemption, the final maturity date as stated in the issue's title may or may not be the date when the contract terminates. Many issues can be retired prior to maturity. The maturity structure of a particular corporation can be accessed using the Bloomberg function DDIS.

Interest Payment Characteristics

The three main interest payment classifications of domestically issued corporate bonds are straight-coupon bonds, zero-coupon bonds, and floating-rate, or variable rate, bonds.

However, before we get into interest-rate characteristics, let us briefly discuss bond types. We refer to the interest rate on a bond as the *coupon*. This is technically wrong because bonds issued today do not have coupons attached. Instead, bonds are represented by a certificate, similar to a stock certificate, with a brief description of the terms printed on both sides. These are called *registered bonds*. The principal amount of the bond is noted on the certificate, and the interest-paying agent or trustee has the responsibility of making payment by check to the registered holder on the due date. Years ago bonds were issued in *bearer* or coupon form, with coupons attached for each interest payment. However, the registered form is considered safer and entails less paperwork. As a matter of fact, the registered bond certificate is on its way out as more and more issues are sold in *book-entry* form. This means that only one master or global certificate is issued. It is held by a central securities depository that issues receipts denoting interests in this global certificate.

Straight-coupon bonds have an interest rate set for the life of the issue, however long or short that may be; they are also called *fixed-rate bonds*. Most fixed-rate bonds in the United States pay interest semiannually and at maturity. For example, consider the 4.75% Notes due 2013 issued by Goldman Sachs Group in July 2003. This bond carries a coupon rate of 4.75% and has a par amount of $1,000. Accordingly, this bond requires payments of $23.75 each January 15 and July 15, including the maturity date of July 15, 2013. On the maturity date, the bond's par amount is also paid. Bonds with annual coupon payments are uncommon in the U.S. capital markets but are the norm in continental Europe.

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Interest on corporate bonds is based on a year of 360 days made up of twelve 30-day months. The corporate calendar day-count convention is referred to as 30/360.

Most fixed-rate corporate bonds pay interest in a standard fashion. However, there are some variations of which one should be aware. Most domestic bonds pay interest in U.S. dollars. However, starting in the early 1980s, issues were marketed with principal and interest payable in other currencies, such as the Australian, New Zealand, or Canadian dollar or the British pound. Generally, interest and principal payments are converted from the foreign currency to U.S. dollars by the paying agent unless it is otherwise notified. The bondholders bear any costs associated with the dollar conversion. Foreign currency issues provide investors with another way of diversifying a portfolio, but not without risk. The holder bears the currency, or exchange-rate, risk in addition to all the other risks associated with debt instruments.

There are a few issues of bonds that can participate in the fortunes of the issuer over and above the stated coupon rate. These are called *participating bonds* because they share in the profits of the issuer or the rise in certain assets over and above certain minimum levels. Another type of bond rarely encountered today is the *income bond*. These bonds promise to pay a stipulated interest rate, but the payment is contingent on sufficient earnings and is in accordance with the definition of available income for interest payments contained in the indenture. Repayment of principal is not contingent. Interest may be cumulative or noncumulative. If payments are cumulative, unpaid interest payments must be made up at some future date. If noncumulative, once the interest payment is past, it does not have to be repaid. Failure to pay interest on income bonds is not an act of default and is not a cause for bankruptcy. Income bonds have been issued by some financially troubled corporations emerging from reorganization proceedings.

Zero-coupon bonds are, just as the name implies, bonds without coupons or an interest rate. Essentially, zero-coupon bonds pay only the principal portion at some future date. These bonds are issued at discounts to par; the difference constitutes the return to the bondholder. The difference between the face amount and the offering price when first issued is called the *original-issue discount* (OID). The rate of return depends on the amount of the discount and the period over which it accretes to par. For example, consider a zero-coupon bond issued by Xerox that matures September 30, 2023 and is priced at 55.835 as of mid-May 2011. In addition, this bond is putable starting on September 30, 2011 at 41.77. These embedded option features will be discussed in more detail shortly.

Zeros were first publicly issued in the corporate market in the spring of 1981 and were an immediate hit with investors. The rapture lasted only a couple of years because of changes in the income tax laws that made ownership more costly on an after-tax basis. Also, these changes reduced the tax advantages to issuers. However, tax-deferred investors, such as pension funds, could still take advantage of zero-coupon issues. One important risk is eliminated in a zero-coupon investment—the reinvestment risk. Because there is no coupon to reinvest, there isn't any reinvestment risk. Of course, although this is beneficial in declining-interest-rate markets, the reverse is true when interest rates are rising. The investor will not be able to reinvest an income stream at rising reinvestment rates. Investors tend to find zeros less attractive in lower-interest-rate markets because compounding is not as meaningful as when rates are higher. Also, the lower the rates are, the more likely it is that they will rise again, making a zero-coupon investment worth less in the eyes of potential holders.

In bankruptcy, a zero-coupon bond creditor can claim the original offering price plus the accretion that represents accrued and unpaid interest to the date of the bankruptcy filing, but not the principal amount of $1,000. Zero-coupon bonds have been sold at deep discounts, and the liability of the issuer at maturity may be substantial. The accretion of the discount on the corporation's books is not put away in a special fund for debt retirement purposes. There are no sinking funds on most of these issues. One hopes that corporate managers invest the proceeds properly and run the corporation for the benefit of all investors so that there will not be a cash crisis at maturity. The potentially large balloon repayment creates a cause for concern among investors. Thus it is most important to invest in higher-quality issues so as to reduce the risk of a potential problem. If one wants to speculate in lower-rated bonds, then that investment should throw off some cash return.

Finally, a variation of the zero-coupon bond is the *deferred-interest bond* (DIB), also known as a *zero-coupon bond*. These bonds generally have been subordinated issues of speculative-grade issuers, also known as *junk*

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issuers. Most of the issues are structured so that they do not pay cash interest for the first five years. At the end of the deferred-interest period, cash interest accrues and is paid semiannually until maturity, unless the bonds are redeemed earlier. The deferred-interest feature allows newly restructured, highly leveraged companies and others with less-than-satisfactory cash flows to defer the payment of cash interest over the early life of the bond. Barring anything untoward, when cash interest payments start, the company will be able to service the debt. If it has made excellent progress in restoring its financial health, the company may be able to redeem or refinance the debt rather than have high interest outlays.

An offshoot of the deferred-interest bond is the pay-in-kind (PIK) debenture. With PIKs, cash interest payments are deferred at the issuer's option until some future date. Instead of just accreting the original-issue discount as with DIBs or zeros, the issuer pays out the interest in additional pieces of the same security. The option to pay cash or in-kind interest payments rests with the issuer, but in many cases the issuer has little choice because provisions of other debt instruments often prohibit cash interest payments until certain indenture or loan tests are satisfied. The holder just gets more pieces of paper, but these at least can be sold in the market without giving up one's original investment; PIKs, DIBs, and zeros do not have provisions for the resale of the interest portion of the instrument. An investment in this type of bond, because it is issued by speculative grade companies, requires careful analysis of the issuer's cash-flow prospects and ability to survive.

SECURITY FOR BONDS

Investors who buy corporate bonds prefer some kind of security underlying the issue. Either real property (using a mortgage) or personal property may be pledged to offer security beyond that of the general credit standing of the issuer. In fact, the kind of security or the absence of a specific pledge of security is usually indicated by the title of a bond issue. However, the best security is a strong general credit that can repay the debt from earnings.

Mortgage Bond

A mortgage bond grants the bondholders a first-mortgage lien on substantially all its properties. This lien provides additional security for the bondholder. As a result, the issuer is able to borrow at a lower rate of interest than if the debt were unsecured. A debenture issue (i.e., unsecured debt) of the same issuer almost surely would carry a higher coupon rate, other things equal. A *lien* is a legal right to sell mortgaged property to satisfy unpaid obligations to bondholders. In practice, foreclosure of a mortgage and sale of mortgaged property are unusual. If a default occurs, there is usually a financial reorganization on the part of the issuer, in which provision is made for settlement of the debt to bondholders. The mortgage lien is important, though, because it gives the mortgage bondholders a very strong bargaining position relative to other creditors in determining the terms of a reorganization.

Often first-mortgage bonds are issued in series with bonds of each series secured equally by the same first mortgage. Many companies, particularly public utilities, have a policy of financing part of their capital requirements continuously by long-term debt. They want some part of their total capitalization in the form of bonds because the cost of such capital is ordinarily less than that of capital raised by sale of stock. Thus, as a principal amount of debt is paid off, they issue another series of bonds under the same mortgage. As they expand and need a greater amount of debt capital, they can add new series of bonds. It is a lot easier and more advantageous to issue a series of bonds under one mortgage and one indenture than it is to create entirely new bond issues with different arrangements for security. This arrangement is called a *blanket mortgage*. When property is sold or released from the lien of the mortgage, additional property or cash may be substituted or bonds may be retired in order to provide adequate security for the debtholders.

When a bond indenture authorizes the issue of additional series of bonds with the same mortgage lien as those already issued, the indenture imposes certain conditions that must be met before an additional series may be issued. Bondholders do not want their security impaired; these conditions are for their benefit. It is common for a first-mortgage bond indenture to specify that property acquired by the issuer subsequent to the granting of the first-mortgage lien shall be subject to the first-mortgage lien. This is termed the *after-acquired clause*. Then the indenture usually permits the issue of additional bonds up to some specified percentage of the value of the after-acquired property, such as 60%. The other 40%,

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or whatever the percentage may be, must be financed in some other way. This is intended to ensure that there will be additional assets with a value significantly greater than the amount of additional bonds secured by the mortgage. Another customary kind of restriction on the issue of additional series is a requirement that earnings in an immediately preceding period must be equal to some number of times the amount of annual interest on all outstanding mortgage bonds including the new or proposed series (1.5, 2, or some other number). For this purpose, *earnings* usually are defined as earnings before income tax. Still another common provision is that additional bonds may be issued to the extent that earlier series of bonds have been paid off.

One seldom sees a bond issue with the term *second mortgage* in its title. The reason is that this term has a connotation of weakness. Sometimes companies get around that difficulty by using such words as *first and consolidated*, *first and refunding*, or *general and refunding mortgage bonds*. Usually this language means that a bond issue is secured by a first mortgage on some part of the issuer's property but by a second or even third lien on other parts of its assets. A general and refunding mortgage bond is generally secured by a lien on all the company's property *subject* to the prior lien of first-mortgage bonds, if any are still outstanding.

Collateral Trust Bonds

Some companies do not own fixed assets or other real property and so have nothing on which they can give a mortgage lien to secure bondholders. Instead, they own securities of other companies; they are *holding companies*, and the other companies are *subsidiaries*. To satisfy the desire of bondholders for security, they pledge stocks, notes, bonds, or whatever other kinds of obligations they own. These assets are termed *collateral* (or personal property), and bonds secured by such assets are *collateral trust bonds*. Some companies own both real property and securities. They may use real property to secure mortgage bonds and use securities for collateral trust bonds. As an example, consider the 10.375% Collateral Trust Bonds due 2018 issued by National Rural Utilities. According to the bond's prospectus, the securities deposited with the trustee include mortgage notes, cash, and other permitted investments.

The legal arrangement for collateral trust bonds is much the same as that for mortgage bonds. The issuer delivers to a corporate trustee under a bond indenture the securities pledged, and the trustee holds them for the benefit of the bondholders. When voting common stocks are included in the collateral, the indenture permits the issuer to vote the stocks so long as there is no default on its bonds. This is important to issuers of such bonds because usually the stocks are those of subsidiaries, and the issuer depends on the exercise of voting rights to control the subsidiaries.

Indentures usually provide that, in event of default, the rights to vote stocks included in the collateral are transferred to the trustee. Loss of the voting right would be a serious disadvantage to the issuer because it would mean loss of control of subsidiaries. The trustee also may sell the securities pledged for whatever prices they will bring in the market and apply the proceeds to payment of the claims of collateral trust bondholders. These rather drastic actions, however, usually are not taken immediately on an event of default. The corporate trustee's primary responsibility is to act in the best interests of bondholders, and their interests may be served for a time at least by giving the defaulting issuer a proxy to vote stocks held as collateral and thus preserve the holding company structure. It also may defer the sale of collateral when it seems likely that bondholders would fare better in a financial reorganization than they would by sale of collateral.

Collateral trust indentures contain a number of provisions designed to protect bondholders. Generally, the market or appraised value of the collateral must be maintained at some percentage of the amount of bonds outstanding. The percentage is greater than 100 so that there will be a margin of safety. If collateral value declines below the minimum percentage, additional collateral must be provided by the issuer. There is almost always provision for withdrawal of some collateral, provided other acceptable collateral is substituted.

Collateral trust bonds may be issued in series in much the same way that mortgage bonds are issued in series. The rules governing additional series of bonds require that adequate collateral must be pledged, and there may be restrictions on the use to which the proceeds of an additional series may be put. All series of bonds are issued under the same indenture and have the same claim on collateral.

Since 2005, an increasing percentage of high yield bond issues have been secured by some mix of mortgages and

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other collateral on a first, second, or even third lien basis. These secured high yield bonds have very customized provisions for issuing additional secured debt and there is some debate about whether the purported collateral for these kinds of bonds will provide greater recoveries in bankruptcy than traditional unsecured capital structures over an economic cycle.

Equipment Trust Certificates

The desire of borrowers to pay the lowest possible rate of interest on their obligations generally leads them to offer their best security and to grant lenders the strongest claim on it. Many years ago, the railway companies developed a way of financing purchase of cars and locomotives, called *rolling stock*, that enabled them to borrow at just about the lowest rates in the corporate bond market.

Railway rolling stock has for a long time been regarded by investors as excellent security for debt. This equipment is sufficiently standardized that it can be used by one railway as well as another. And it can be readily moved from the tracks of one railroad to those of another. There is generally a good market for lease or sale of cars and locomotives. The railroads have capitalized on these characteristics of rolling stock by developing a legal arrangement for giving investors a legal claim on it that is different from, and generally better than, a mortgage lien.

The legal arrangement is one that vests legal title to railway equipment in a trustee, which is better from the standpoint of investors than a first-mortgage lien on property. A railway company orders some cars and locomotives from a manufacturer. When the job is finished, the manufacturer transfers the legal title to the equipment to a trustee. The trustee leases it to the railroad that ordered it and at the same time sells *equipment trust certificates* (ETCs) in an amount equal to a large percentage of the purchase price, normally 80%. Money from the sale of certificates is paid to the manufacturer. The railway company makes an initial payment of rent equal to the balance of the purchase price, and the trustee gives that money to the manufacturer. Thus the manufacturer is paid off. The trustee collects lease rental money periodically from the railroad and uses it to pay interest and principal on the certificates. These interest payments are known as dividends. The amounts of lease rental payments are worked out carefully so that they are enough to pay the equipment trust certificates. At the end of some period of time, such as 15 years, the certificates are paid off, the trustee sells the equipment to the railroad for some nominal price, and the lease is terminated.

Railroad ETCs usually are structured in serial form; that is, a certain amount becomes payable at specified dates until the final installment. For example, a $60 million ETC might mature $4 million on each June 15 from 2000 through 2014. Each of the 15 maturities may be priced separately to reflect the shape of the yield curve, investor preference for specific maturities, and supply-and-demand considerations. The advantage of a serial issue from the investor's point of view is that the repayment schedule matches the decline in the value of the equipment used as collateral. Hence principal repayment risk is reduced. From the issuer's side, serial maturities allow for the repayment of the debt periodically over the life of the issue, making less likely a crisis at maturity due to a large repayment coming due at one time.

The beauty of this arrangement from the viewpoint of investors is that the railroad does not legally own the rolling stock until all the certificates are paid. In case the railroad does not make the lease rental payments, there is no big legal hassle about foreclosing a lien. The trustee owns the property and can take it back because failure to pay the rent breaks the lease. The trustee can lease the equipment to another railroad and continue to make payments on the certificates from new lease rentals.

This description emphasizes the legal nature of the arrangement for securing the certificates. In practice, these certificates are regarded as obligations of the railway company that leased the equipment and are shown as liabilities on its balance sheet. In fact, the name of the railway appears in the title of the certificates. In the ordinary course of events, the trustee is just an intermediary who performs the function of holding title, acting as lessor, and collecting the money to pay the certificates. It is significant that even in the worst years of a depression, railways have paid their equipment trust certificates, although they did not pay bonds secured by mortgages. Although railroads have issued the largest amount of equipment trust certificates, airlines also have used this form of financing.

Debenture Bonds

While bondholders prefer to have security underlying their bonds, all else equal, most bonds issued are

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unsecured. These unsecured bonds are called *debentures*. With the exception of the utilities and structured products, nearly all other corporate bonds issued are unsecured.

Debentures are not secured by a specific pledge of designated property, but this does not mean that they have no claim on the property of issuers or on their earnings. Debenture bondholders have the claim of general creditors on all assets of the issuer not pledged specifically to secure other debt. And they even have a claim on pledged assets to the extent that these assets have value greater than necessary to satisfy secured creditors. In fact, if there are no pledged assets and no secured creditors, debenture bondholders have first claim on all assets along with other general creditors.

These unsecured bonds are sometimes issued by companies that are so strong financially and have such a high credit rating that to offer security would be superfluous. Such companies simply can turn a deaf ear to investors who want security and still sell their debentures at relatively low interest rates. But debentures sometimes are issued by companies that have already sold mortgage bonds and given liens on most of their property. These debentures rank below the mortgage bonds or collateral trust bonds in their claim on assets, and investors may regard them as relatively weak. This is the kind that bears the higher rates of interest.

Even though there is no pledge of security, the indentures for debenture bonds may contain a variety of provisions designed to afford some protection to investors. Sometimes the amount of a debenture bond issue is limited to the amount of the initial issue. This limit is to keep issuers from weakening the position of debenture holders by running up additional unsecured debt. Sometimes additional debentures may be issued a specified number of times in a recent accounting period, provided that the issuer has earned its bond interest on all existing debt plus the additional issue.

If a company has no secured debt, it is customary to provide that debentures will be secured equally with any secured bonds that may be issued in the future. This is known as the *negative-pledge clause*. Some provisions of debenture bond issues are intended to protect bondholders against other issuer actions when they might be too harmful to the creditworthiness of the issuer. For example, some provisions of debenture bond issues may require maintaining some level of net worth, restrict selling major assets, or limit paying dividends in some cases. However, the trend in recent years, at least with investment-grade companies, is away from indenture restrictions.

Subordinated and Convertible Debentures

Many corporations issue *subordinated debenture bonds*. The term *subordinated* means that such an issue ranks after secured debt, after debenture bonds, and often after some general creditors in its claim on assets and earnings. Owners of this kind of bond stand last in line among creditors when an issuer fails financially.

Because subordinated debentures are weaker in their claim on assets, issuers would have to offer a higher rate of interest unless they also offer some special inducement to buy the bonds. The inducement can be an option to convert bonds into stock of the issuer at the discretion of bondholders. If the issuer prospers and the market price of its stock rises substantially in the market, the bondholders can convert bonds to stock worth a great deal more than what they paid for the bonds. This conversion privilege also may be included in the provisions of debentures that are not subordinated.

The bonds may be convertible into the common stock of a corporation other than that of the issuer. Such issues are called *exchangeable bonds*. There are also issues indexed to a commodity's price or its cash equivalent at the time of maturity or redemption.

Guaranteed Bonds

Sometimes a corporation may guarantee the bonds of another corporation. Such bonds are referred to as *guaranteed bonds*. The guarantee, however, does not mean that these obligations are free of default risk. The safety of a guaranteed bond depends on the financial capability of the guarantor to satisfy the terms of the guarantee, as well as the financial capability of the issuer. The terms of the guarantee may call for the guarantor to guarantee the payment of interest and/or repayment of the principal. A guaranteed bond may have more than one corporate guarantor. Each guarantor may be responsible for not only its pro rata share but also the entire amount guaranteed by the other guarantors.

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ALTERNATIVE MECHANISMS TO RETIRE DEBT BEFORE MATURITY

We can partition the alternative mechanisms to retire debt into two broad categories—namely, those mechanisms that must be included in the bond's indenture in order to be used and those mechanisms that can be used without being included in the bond's indenture. Among those debt retirement mechanisms included in a bond's indenture are the following: call and refunding provisions, sinking funds, maintenance and replacement funds, and redemption through sale of assets. Alternatively, some debt retirement mechanisms are not required to be included in the bond indenture (e.g., fixed-spread tender offers).

Call and Refunding Provisions

Many corporate bonds contain an embedded option that gives the issuer the right to buy the bonds back at a fixed price either in whole or in part prior to maturity. The feature is known as a *call provision*. The ability to retire debt before its scheduled maturity date is a valuable option for which bondholders will demand compensation ex-ante. All else equal, bondholders will pay a lower price for a callable bond than an otherwise identical option-free (i.e., straight) bond. The difference between the price of an option-free bond and the callable bond is the value of the embedded call option.

Conventional wisdom suggests that the most compelling reason for corporations to retire their debt prior to maturity is to take advantage of declining borrowing rates. If they are able to do so, firms will substitute new, lower-cost debt for older, higher-cost issues. However, firms retire their debt for other reasons as well. For example, firms retire their debt to eliminate restrictive covenants, to alter their capital structure, to increase shareholder value, or to improve financial/managerial flexibility. There are two types of call provisions included in corporate bonds—a fixed-price call and a make-whole call. We will discuss each in turn.

Fixed-Price Call Provision

With a standard fixed-price call provision, the bond issuer has the option to buy back some or all of the bond issue prior to maturity at a fixed price. The fixed price is termed the *call price*. Normally, the bond's indenture contains a call-price schedule that specifies when the bonds can be called and at what prices. The call prices generally start at a substantial premium over par and decline toward par over time such that in the final years of a bond's life, the call price is usually par.

In some corporate issues, bondholders are afforded some protection against a call in the early years of a bond's life. This protection usually takes one of two forms. First, some callable bonds possess a feature that prohibits a bond call for a certain number of years. Second, some callable bonds prohibit the bond from being refunded for a certain number of years. Such a bond is said to be *nonrefundable*. Prohibition of refunding precludes the redemption of a bond issue if the funds used to repurchase the bonds come from new bonds being issued with a lower coupon than the bonds being redeemed. However, a refunding prohibition does not prevent the redemption of bonds from funds obtained from other sources (e.g., asset sales, the issuance of equity, etc.). Call prohibition provides the bondholder with more protection than a bond that has a refunding prohibition that is otherwise callable.[1]

Make-Whole Call Provision

In contrast to a standard fixed-price call, a make-whole call price is calculated as the present value of the bond's remaining cash flows subject to a floor price equal to par value. The discount rate used to determine the present value is the yield on a comparable-maturity Treasury security plus a contractually specified *make-whole call premium*. For example, in November 2010, Coca-Cola sold $1 billion of 3.15% Notes due November 15, 2020. These notes are redeemable at any time either in whole or in part at the issuer's option. The redemption price is the greater of (1) 100% of the principal amount plus accrued interest or (2) the make whole redemption price, which is equal to the sum of the present value of the remaining coupon and principal payments discounted at the Treasury rate plus 10 basis points. The spread of 10 basis points is the aforementioned make-whole call premium. Thus the make-whole call price is essentially a floating call price that moves inversely with the level of interest rates.

[1] There are, of course, exceptions to a call prohibition, such as sinking funds and redemption of the debt under certain mandatory provisions.

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The Treasury rate is calculated in one of two ways. One method is to use a constant-maturity Treasury (CMT) yield as the Treasury rate. CMT yields are published weekly by the Federal Reserve in its statistical release H.15. The maturity of the CMT yield will match the bond's remaining maturity (rounded to the nearest month). If there is no CMT yield that exactly corresponds with the bond's remaining maturity, a linear interpolation is employed using the yields of the two closest available CMT maturities. Once the CMT yield is determined, the discount rate for the bond's remaining cash flows is simply the CMT yield plus the make-whole call premium specified in the indenture.

Another method of determining the Treasury rate is to select a U.S. Treasury security having a maturity comparable with the remaining maturity of the make-whole call bond in question. This selection is made by a primary U.S. Treasury dealer designated in the bond's indenture. An average price for the selected Treasury security is calculated using the price quotations of multiple primary dealers. The average price is then used to calculate a bond-equivalent yield. This yield is then used as the Treasury rate.

Make-whole call provisions were first introduced in publicly traded corporate bonds in 1995. Bonds with make-whole call provisions are now issued routinely. Moreover, the make-whole call provision is growing in popularity while bonds with fixed-price call provisions are declining. Figure 20-1 presents a graph that shows the total par amount outstanding of corporate bonds issued in billions of dollars by type of bond (straight, fixed-price call, make-whole call) for years 1995 to 2009.[2] This sample of bonds contains all debentures issued on and after January 1, 1995, that might have certain characteristics.[3] These data suggest that the make-whole call provision is rapidly becoming the call feature of choice for corporate bonds.

The primary advantage from the firm's perspective of a make-whole call provision relative to a fixed-price call is a lower cost. Since the make-whole call price floats inversely with the level of Treasury rates, the issuer will not exercise the call to buy back the debt merely because its borrowing rates have declined. Simply put, the pure refunding motive is virtually eliminated. This feature will reduce the upfront compensation required by bondholders to hold make-whole call bonds versus fixed-price call bonds.

Sinking-Fund Provision

Term bonds may be paid off by operation of a *sinking fund*. These last two words are often misunderstood to mean that the issuer accumulates a fund in cash, or in assets readily sold for cash, that is used to pay bonds at maturity. It had that meaning many years ago, but too often the money supposed to be in a sinking fund was not all there when it was needed. In modem practice, there is no fund, and *sinking* means that money is applied periodically to redemption of bonds before maturity. Corporate bond indentures require the issuer to retire a specified portion of an issue each year. This kind of provision for repayment of corporate debt may be designed to liquidate all of a bond issue by the maturity date, or it may

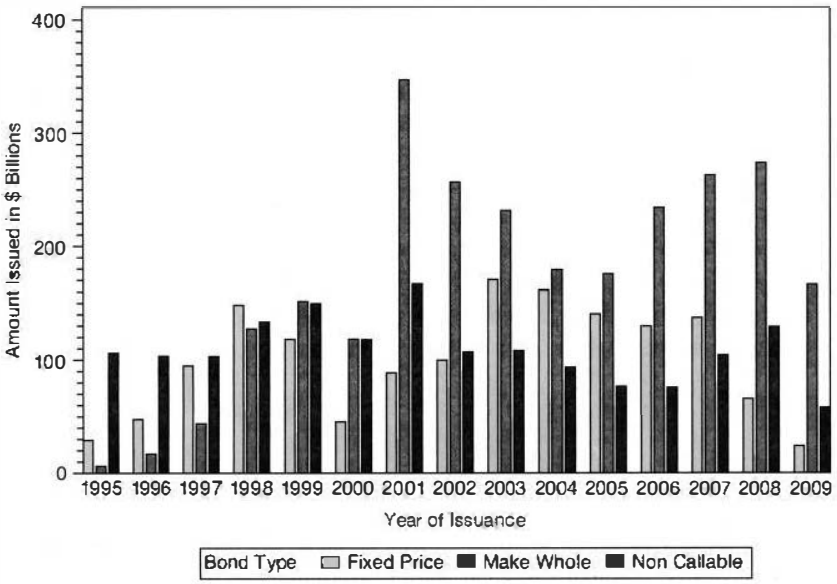

FIGURE 20-1 Total par amount of corporate bonds outstanding by type of call provision.

[2] Our data source is the Fixed Income Securities Database jointly published by LJS Global Information Services and Arthur Warga at the University of Houston.

[3] These characteristics include such things as the offering amount had to be at least $25 million and excluded medium-term notes and bonds with other embedded options (e.g., bonds that were potable or convertible). See Scott Brown and Eric Powers, "The Life Cycle of Make-Whole Call Provisions," *Working Paper*, March 2011.

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be arranged to pay only a part of the total by the end of the term. As an example, consider a $150 million issue by Westvaco in June 1997. The bonds carry a 7.5% coupon and mature on June 15, 2027. The bonds' indenture provides for an annual sinking-fund payment of $7.5 million or $15 million to be determined on an annual basis.

The issuer may satisfy the sinking-fund requirement in one of two ways. A cash payment of the face amount of the bonds to be retired may be made by the corporate debtor to the trustee. The trustee then calls the bonds pro rata or by lot for redemption. Bonds have serial numbers, and numbers may be selected randomly for redemption. Owners of bonds called in this manner turn them in for redemption; *interest payments stop at the redemption date*. Alternatively, the issuer can deliver to the trustee bonds with a total face value equal to the amount that must be retired. The bonds are purchased by the *issuer* in the open market. This option is elected by the issuer when the bonds are selling below par. A few corporate bond indentures, however, prohibit the open-market purchase of the bonds by the issuer.

Many electric utility bond issues can satisfy the sinking-fund requirement by a third method. Instead of actually retiring bonds, the company may certify to the trustee that it has used unfunded property credits in lieu of the sinking fund. That is, it has made property and plant investments that have not been used for issuing bonded debt. For example, if the sinking-fund requirement is $1 million, it may give the trustee $1 million in cash to call bonds, it may deliver to the trustee $1 million of bonds it purchased in the open market, or it may certify that it made additions to its property and plant in the required amount, normally $1,667 of plant for each $1,000 sinking-fund requirement. In this case it could satisfy the sinking fund with certified property additions of $1,667,000.

The issuer is granted a special call price to satisfy any sinking-fund requirement. Usually, the sinking-fund call price is the par value if the bonds were originally sold at par. When issued at a price in excess of par, the sinking-fund call price generally starts at the issuance price and scales down to par as the issue approaches maturity.

There are two advantages of a sinking-fund requirement from the bondholder's perspective. First, default risk is reduced because of the orderly retirement of the issue before maturity. Second, if bond prices decline as a result of an increase in interest rates, price support may be provided by the issuer or its fiscal agent because it must enter the market on the buy side in order to satisfy the sinking-fund requirement. However, the disadvantage is that the bonds may be called at the special sinking-fund call price at a time when interest rates are lower than rates prevailing at the time of issuance. In that case, the bonds will be selling above par but may be retired by the issuer at the special call price that may be equal to par value.

Usually, the periodic payments required for sinking-fund purposes will be the same for each period. Gas company issues often have increasing sinking-fund requirements. However, a few indentures might permit variable periodic payments, where the periodic payments vary based on prescribed conditions set forth in the indenture. The most common condition is the level of earnings of the issuer. In such cases, the periodic payments vary directly with earnings. An issuer prefers such flexibility; however, an investor may prefer fixed periodic payments because of the greater default risk protection provided under this arrangement.

Many corporate bond indentures include a provision that grants the issuer the option to retire more than the amount stipulated for sinking-fund retirement. This option, referred to as an *accelerated sinking-fund provision*, effectively reduces the bondholder's call protection because, when interest rates decline, the issuer may find it economically advantageous to exercise this option at the special sinking-fund call price to retire a substantial portion of an outstanding issue.

Sinking fund provisions have fallen out of favor for most companies, but they used to be fairly common for public utilities, pipeline issuers, and some industrial issues. Finance issues almost never include a sinking fund provision. There can be a mandatory sinking fund where bonds have to be retired or, as mentioned earlier, a nonmandatory sinking fund in which it may use certain property credits for the sinking-fund requirement. If the sinking fund applies to a particular issue, it is called a *specific sinking fund*. There are also *nonspecific sinking funds* (also known as *funnel*, *tunnel*, *blanket*, or *aggregate sinking funds*), where the requirement is based on the total bonded debt outstanding of an issuer. Generally, it might require a sinking-fund payment of 1% of all bonds outstanding as of year-end. The issuer can apply the requirement to one particular issue or to any other issue or issues. Again, the blanket sinking fund may be mandatory

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(where bonds have to be retired) or nonmandatory (whereby it can use unfunded property additions).

Maintenance and Replacement Funds

Maintenance and replacement fund (M&R) provisions first appeared in bond indentures of electric utilities subject to regulation by the Securities and Exchange Commission (SEC) under the Public Holding Company Act of 1940. It remained in the indentures even when most of the utilities were no longer subject to regulation under the act. The original motivation for their inclusion is straightforward. Property is subject to economic depreciation, and the replacement fund ostensibly helps to maintain the integrity of the property securing the bonds. An M&R differs from a sinking fund in that the M&R only helps to maintain the value of the security backing the debt, whereas a sinking fund is designed to improve the security backing the debt. Although it is more complex, it is similar in spirit to a provision in a home mortgage requiring the homeowner to maintain the home in good repair.

An M&R requires a utility to determine annually the amounts necessary to satisfy the fund and any shortfall. The requirement is based on a formula that is usually some percentage (e.g., 15%) of adjusted gross operating revenues. The difference between what is required and the actual amount expended on maintenance is the shortfall. The shortfall is usually satisfied with unfunded property additions, but it also can be satisfied with cash. The cash can be used for the retirement of debt or withdrawn on the certification of unfunded property credits.

While the retirement of debt through M&R provisions is not as common as it once was, M&Rs are still relevant, so bond investors should be cognizant of their presence in an indenture. For example, in April 2000, PPL Electric Utilities Corporation redeemed all its outstanding 9.25% coupon series first-mortgage bonds due in 2019 using an M&R provision. The special redemption price was par. The company's stated purpose of the call was to reduce interest expense.

Redemption through the Sale of Assets and Other Means

Because mortgage bonds are secured by property, bondholders want the integrity of the collateral to be maintained. Bondholders would not want a company to sell a plant (which has been pledged as collateral) and then to use the proceeds for a distribution to shareholders. Therefore, release-of-property and substitution-of property clauses are found in most secured bond indentures.

As an illustration, Texas-New Mexico Power Co. issued $130 million in first-mortgage bonds in January 1992 that carried a coupon rate of 11.25%. The bonds were callable beginning in January 1997 at a call price of 105. Following the sale of six of its utilities, Texas-New Mexico Power called the bonds at par in October 1995, well before the first call date. As justification for the call, Texas-New Mexico Power stated that it was forced to sell the six utilities by municipalities in northern Texas, and as a result, the bonds were callable under the eminent domain provision in the bond's indenture. The bondholders sued, stating that the bonds were redeemed in violation of the indenture. In April 1997, the court found for the bondholders, and they were awarded damages, as well as lost interest. In the judgment of the court, while the six utilities were under the threat of condemnation, no eminent domain proceedings were initiated.

Tender Offers

In addition to those methods specified in the indenture, firms have other tools for extinguishing debt prior to its stated maturity. At any time a firm may execute a tender offer and announce its desire to buy back specified debt issues. Firms employ tender offers to eliminate restrictive covenants or to refund debt. Usually the tender offer is for "any and all" of the targeted issue, but it also can be for a fixed dollar amount that is less than the outstanding face value. An offering circular is sent to the bondholders of record stating the price the firm is willing to pay and the window of time during which bondholders can sell their bonds back to the firm. If the firm perceives that participation is too low, the firm can increase the tender offer price and extend the tender offer window. When the tender offer expires, all participating bondholders tender their bonds and receive the same cash payment from the firm.

In recent years, tender offers have been executed using a fixed spread as opposed to a fixed price.[4] In a fixed-spread tender offer, the tender offer price is equal to the

[4] See Steven V. Mann and Eric A. Powers, "Determinants of Bond Tender Premiums and the Percentage Tendered," *Journal of Banking and Finance*, March 2007, pp. 547–566.

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present value of the bond's remaining cash flows either to maturity or the next call date if the bond is callable. The present-value calculation occurs immediately after the tender offer expires. The discount rate used in the calculation is equal to the yield-to-maturity on a comparable-maturity Treasury or the associated CMT yield plus the specified fixed spread. Fixed-spread tender offers eliminate the exposure to interest-rate risk for both bondholders and the firm during the tender offer window.

CREDIT RISK

All corporate bonds are exposed to credit risk, which includes *credit default risk* and *credit-spread risk*.

Measuring Credit Default Risk

Any bond investment carries with it the uncertainty as to whether the issuer will make timely payments of interest and principal as prescribed by the bond's indenture. This risk is termed *credit default risk* and is the risk that a bond issuer will be unable to meet its financial obligations. Institutional investors have developed tools for analyzing information about both issuers and bond issues that assist them in accessing credit default risk. However, most individual bond investors and some institutional bond investors do not perform any elaborate credit analysis. Instead, they rely largely on bond ratings published by the major rating agencies that perform the credit analysis and publish their conclusions in the form of ratings. The three major nationally recognized statistical rating organizations (NRSROs) in the United States are Fitch Ratings, Moody's, and Standard & Poor's. These ratings are used by market participants as a factor in the valuation of securities on account of their independent and unbiased nature.

The ratings systems use similar symbols, as shown in Table 20-1. In addition to the generic rating category, Moody's employs a numerical modifier of 1, 2, or 3 to indicate the relative standing of a particular issue within a rating category. This modifier is called a *notch*. Both Standard & Poor's and Fitch use a plus (+) and a minus (−) to convey the same information. Bonds rated triple B or higher are referred to as *investment-grade bonds*. Bonds rated below triple B are referred to as *non-investment-grade bonds* or, more popularly, *high-yield bonds* or *junk bonds*.

Credit ratings can and do change over time. A *rating transition table*, also called a *rating migration table*, is a table that shows how ratings change over some specified time period. Table 20-2 presents a hypothetical rating transition table for a one-year time horizon. The ratings beside each of the rows are the ratings at the start of the year. The ratings at the head of each column are the ratings at the end of the year. Accordingly, the first cell in the table tells that 93.20% of the issues that were rated AAA at the beginning of the year still had that rating at the end. These tables are published periodically by the three rating agencies and can be used to access changes in credit default risk.

Measuring Credit-Spread Risk

The *credit-spread* is the difference between a corporate bond's yield and the yield on a comparable-maturity benchmark Treasury security.[5] Credit spreads are so named because the presumption is that the difference in yields is due primarily to the corporate bond's exposure to credit risk. This is misleading, however, because the risk profile of corporate bonds differs from Treasuries on other dimensions; namely, corporate bonds are less liquid and often have embedded options.

Credit-spread risk is the risk of financial loss or the underperformance of a portfolio resulting from changes in the level of credit spreads used in the marking to market of a fixed income product. Credit spreads are driven by both macro-economic forces and issue-specific factors. Macro-economic forces include such things as the level and slope of the Treasury yield curve, the business cycle, and consumer confidence. Correspondingly, the issue-specific factors include such things as the corporation's financial position and the future prospects of the firm and its industry.

One method used commonly to measure credit-spread risk is *spread duration*. Spread duration is the approximate percentage change in a bond's price for a 100 basis point change in the credit-spread assuming that the Treasury rate is unchanged. For example, if a bond has a spread duration of 3, this indicates that for a 100 basis

[5] The U.S. Treasury yield is a common but by no means the only choice for a benchmark to compute credit spreads. Other reasonable choices include the swap curve or the agency yield curve.

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TABLE 20-1 Corporate Bond Credit Ratings

Fitch	Moody's	S&P	Summary Description
Investment Grade			
AAA	Aaa	AAA	Gilt edged, prime, maximum safety, lowest risk, and when sovereign borrower considered "default-free"
AA+	Aa1	AA+	
AA	Aa2	AA	High-grade, high credit quality
AA−	Aa3	AA−	
A+	A1	A+	
A	A2	A	Upper-medium grade
A−	A3	A−	
BBB+	Baa1	BBB+	
BBB	Baa2	BBB	Lower-medium grade
BBB−	Baa3	BBB−	
Speculative Grade			
BB+	Ba1	BB+	
BB	Ba2	BB	Low grade; speculative
BB−	Ba3	BB−	
B+	B1		
B	B	B	Highly speculative
B−	B3		
Predominantly Speculative, Substantial Risk or In Default			
CCC+		CCC+	
CCC	Caa	CCC	Substantial risk, in poor standing
CC	Ca	CC	May be in default, very speculative
C	C	C	Extremely speculative
		CI	Income bonds—no interest being paid
DDD			
DD			Default
D	D		

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TABLE 20-2 Hypothetical One-Year Rating Transition Table

Rating at Start of Year	Rating at End of Year								
	AAA	AA	A	BBB	BB	B	CCC	D	Total
AAA	93.20	6.00	0.60	0.12	0.08	0.00	0.00	0.00	100
AA	1.60	92.75	5.07	0.36	0.11	0.07	0.03	0.01	100
A	0.18	2.65	91.91	4.80	0.37	0.02	0.02	0.05	100
BBB	0.04	0.30	5.20	87.70	5.70	0.70	0.16	0.20	100
BB	0.03	0.11	0.61	6.80	81.65	7.10	2.60	1.10	100
B	0.01	0.09	0.55	0.88	7.90	75.67	8.70	6.20	100
CCC	0.00	0.01	0.31	0.84	2.30	8.10	62.54	25.90	100

point change in the credit-spread, the bond's price should change be approximately 3%.

EVENT RISK

In recent years, one of the more talked-about topics among corporate bond investors is *event risk*. Over the last couple of decades, corporate bond indentures have become less restrictive, and corporate managements have been given a free rein to do as they please without regard to bondholders. Management's main concern or duty is to enhance shareholder wealth. As for the bondholder, all a company is required to do is to meet the terms of the bond indenture, including the payment of principal and interest. With few restrictions and the optimization of share holder wealth of paramount importance for corporate managers, it is no wonder that bondholders became concerned when merger mania and other events swept the nation's boardrooms. Events such as decapitalizations, restructurings, recapitalizations, mergers, acquisitions, leveraged buyouts, and share repurchases, among other things, often caused substantial changes in a corporation's capital structure, namely, greatly increased leverage and decreased equity. Bondholders' protection was sharply reduced and debt quality ratings lowered, in many cases to speculative-grade categories. Along with greater risk came lower bond valuations. Shareholders were being enriched at the expense of bondholders. It is important to keep in mind the distinction between event risk and headline risk. Headline risk is the uncertainty engendered by the firm's media coverage that causes investors to alter their perception of the firm's prospects. Headline risk is present regardless of the veracity of the media coverage.

In reaction to the increased activity of leveraged buyouts and strategic mergers and acquisitions, some companies incorporated "poison puts" in their indentures. These are designed to thwart unfriendly takeovers by making the target company unpalatable to the acquirer. The poison put provides that the bondholder can require the company to repurchase the debt under certain circumstances arising out of specific designated events such as a change in control. Poison puts may not deter a proposed acquisition but could make it more expensive. Many times, in addition to a designated event, a rating change to below investment grade must occur within a certain period for the put to be activated. Some issues provide for a higher interest rate instead of a put as a designated event remedy.

At times, event risk has caused some companies to include other special debt-retirement features in their indentures. An example is the *maintenance of net worth clause* included in the indentures of some lower-rated

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bond issues. In this case, an issuer covenants to maintain its net worth above a stipulated level, and if it fails to do so, it must begin to retire its debt at par. Usually the redemptions affect only part of the issue and continue periodically until the net worth recovers to an amount above the stated figure or the debt is retired. In other cases, the company is required only to *offer to redeem* a required amount. An offer to redeem is not mandatory on the bondholders' part; only those holders who want their bonds redeemed need do so. In a number of instances in which the issuer is required to call bonds, the bondholders may elect not to have bonds redeemed. This is not much different from an offer to redeem. It may protect bondholders from the redemption of the high-coupon debt at lower interest rates. However, if a company's net worth declines to a level low enough to activate such a call, it probably would be prudent to have one's bonds redeemed.

Protecting the value of debt investments against the added risk caused by corporate management activity is not an easy job. Investors should analyze the issuer's fundamentals carefully to determine if the company may be a candidate for restructuring. Attention to news and equity investment reports can make the task easier. Also, the indenture should be reviewed to see if there are any protective covenant features. However, there may be loopholes that can be exploited by sharp legal minds. Of course, large portfolios can reduce risk with broad diversification among industry lines, but price declines do not always affect only the issue at risk; they also can spread across the board and take the innocent down with them. This happened in the fall of 1988 with the leveraged buyout of RJR Nabisco, Inc. The whole industrial bond market suffered as buyers and traders withdrew from the market, new issues were postponed, and secondary market activity came to a standstill. The impact of the initial leveraged buyout bid announcement on yield spreads for RJR Nabisco's debt to a benchmark Treasury increased from about 100 to 350 basis points. The RJR Nabisco transaction showed that size was not an obstacle. Therefore, other large firms that investors previously thought were unlikely candidates for a leveraged buyout were fair game. The spillover effect caused yield spreads to widen for other major corporations. This phenomenon was repeated in the mid-2000s with the buyout of large, investment grade public companies such as Alltel, First Data, and Hilton Hotels.

HIGH-YIELD BONDS

As noted, high-yield bonds are those rated below investment grade by the ratings agencies. These issues are also known as *junk bonds*. Despite the negative connotation of the term *junk*, not all bonds in the high-yield sector are on the verge of default or bankruptcy. Many of these issues are on the fringe of the investment-grade sector.

Types of Issuers

Several types of issuers fall into the less-than-investment-grade high-yield category. These categories are discussed below.

Original Issuers

Original issuers include young, growing concerns lacking the stronger balance sheet and income statement profile of many established corporations but often with lots of promise. Also called *venture-capital situations* or *growth or emerging market companies*, the debt is often sold with a story projecting future financial strength. From this we get the term *story bond*. There are also the established operating firms with financials neither measuring up to the strengths of investment grade corporations nor possessing the weaknesses of companies on the verge of bankruptcy. Subordinated debt of investment-grade issuers may be included here. A bond rated at the bottom rung of the investment-grade category (Baa and BBB) or at the top end of the speculative-grade category (Ba and BB) is referred to as a "businessman's risk."

Fallen Angels

"Fallen angels" are companies with investment-grade-rated debt that have come on hard times with deteriorating balance sheet and income statement financial parameters. They may be in default or near bankruptcy. In these cases, investors are interested in the workout value of the debt in a reorganization or liquidation, whether within or outside the bankruptcy courts. Some refer to these issues as "special situations." Over the years, they have fallen on hard times; some have recovered, and others have not.

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Restructurings and Leveraged Buyouts

These are companies that have deliberately increased their debt burden with a view toward maximizing shareholder value. The shareholders may be the existing public group to which the company pays a special extraordinary dividend, with the funds coming from borrowings and the sale of assets. Cash is paid out, net worth decreased, and leverage increased, and ratings drop on existing debt. Newly issued debt gets junk-bond status because of the company's weakened financial condition.

In a leveraged buyout (LBO), a new and private shareholder group owns and manages the company. The debt issue's purpose may be to retire other debt from commercial and investment banks and institutional investors incurred to finance the LBO. The debt to be retired is called *bridge financing* because it provides a bridge between the initial LBO activity and the more permanent financing. One example is Ann Taylor, Inc.'s 1989 debt financing for bridge loan repayment. The proceeds of BCI Holding Corporation's 1986 public debt financing and bank borrowings were used to make the required payments to the common shareholders of Beatrice Companies, pay issuance expenses, and retire certain Beatrice debt and for working capital.

Unique Features of Some Issues

Often actions taken by management that result in the assignment of a non investment-grade bond rating result in a heavy interest-payment burden. This places severe cash-flow constraints on the firm. To reduce this burden, firms involved with heavy debt burdens have issued bonds with *deferred coupon structures* that permit the issuer to avoid using cash to make interest payments for a period of three to seven years. There are three types of deferred-coupon structures: (1) deferred-interest bonds, (2) step-up bonds, and (3) payment in-kind bonds.

Deferred-interest bonds are the most common type of deferred-coupon structure. These bonds sell at a deep discount and do not pay interest for an initial period, typically from three to seven years. (Because no interest is paid for the initial period, these bonds are sometimes referred to as "zero-coupon bonds.") *Step-up bonds* do pay coupon interest, but the coupon rate is low for an initial period and then increases ("steps up") to a higher coupon rate. Finally, *payment-in-kind (PIK) bonds* give the issuers an option to pay cash at a coupon payment date or give the bondholder a similar bond (i.e., a bond with the same coupon rate and a par value equal to the amount of the coupon payment that would have been paid). The period during which the issuer can make this choice varies from five to ten years.

Sometimes an issue will come to market with a structure allowing the issuer to reset the coupon rate so that the bond will trade at a predetermined price.[6] The coupon rate may reset annually or even more frequently, or reset only one time over the life of the bond. Generally, the coupon rate at the reset date will be the average of rates suggested by two investment banking firms. The new rate will then reflect (1) the level of interest rates at the reset date and (2) the credit-spread the market wants on the issue at the reset date. This structure is called an *extendible reset bond*.

Notice the difference between an extendible reset bond and a typical floating-rate issue. In a floating-rate issue, the coupon rate resets according to a fixed spread over the reference rate, with the index spread specified in the indenture. The amount of the index spread reflects market conditions at the time the issue is offered. The coupon rate on an extendible reset bond, in contrast, is reset based on market conditions (as suggested by several investment banking firms) at the time of the reset date. Moreover, the new coupon rate reflects the new level of interest rates and the new spread that investors seek.

The advantage to investors of extendible reset bonds is that the coupon rate will reset to the market rate—both the level of interest rates and the credit-spread—in principle keeping the issue at par value. In fact, experience with extendible reset bonds has not been favorable during periods of difficulties in the high-yield bond market. The sudden substantial increase in default risk has meant that the rise in the rate needed to keep the issue at par value was so large that it would have insured bankruptcy of the issuer. As a result, the rise in the coupon rate has been insufficient to keep the issue at the stipulated price.

[6] Most of the bonds have a coupon reset formula that requires the issuer to reset the coupon so that the bond will trade at a price of $101.

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Some speculative-grade bond issues started to appear in 1992 granting the issuer a limited right to redeem a portion of the bonds during the noncall period if the proceeds are from an initial public stock offering. Called "clawback" provisions, they merit careful attention by inquiring bond investors. The provision appears in the vast majority of new speculative-grade bond issues, and sometimes allow even private sales of stock to be used for the clawback. The provision usually allows 35% of the issue to be retired during the first three years after issuance, at a price of par plus one year of coupon. Investors should be forewarned of claw backs because they can lose bonds at the point in time just when the issuer's finances have been strengthened through access to the equity market. Also, the redemption may reduce the amount of the outstanding bonds to a level at which their liquidity in the aftermarket may suffer.

DEFAULT RATES AND RECOVERY RATES

We now turn our attention to the various aspects of the historical performance of corporate issuers with respect to fulfilling their obligations to bondholders. Specifically, we will look at two aspects of this performance. First, we will look at the default rate of corporate borrowers. From an investment perspective, default rates by themselves are not of paramount significance; it is perfectly possible for a portfolio of bonds to suffer defaults and to outperform Treasuries at the same time, provided the yield spread of the portfolio is sufficiently high to offset the losses from default. Furthermore, because holders of defaulted bonds typically recover some percentage of the face amount of their investment, the *default loss rate* is substantially lower than the default rate. Therefore, it is important to look at default loss rates or, equivalently, *recovery rates*.

Default Rates

A default rate can be measured in different ways. A simple way to define a default rate is to use the issuer as the unit of study. A default rate is then measured as the number of issuers that default divided by the total number of issuers at the beginning of the year. This measure gives no recognition to the amount defaulted nor the total amount of issuance. Moody's, for example, uses this default-rate statistic in its study of default rates.[7] The rationale for ignoring dollar amounts is that the credit decision of an investor does not increase with the size of the issuer. The second measure is to define the default rate as the par value of all bonds that defaulted in a given calendar year divided by the total par value of all bonds outstanding during the year. Edward Altman, who has performed extensive analyses of default rates for speculative-grade bonds, measures default rates in this way. We will distinguish between the default-rate statistic below by referring to the first as the *issuer default rate* and the second as the *dollar default rate*.

With either default-rate statistic, one can measure the default for a given year or an average annual default rate over a certain number of years. Researchers who have defined dollar default rates in terms of an average annual default rate over a certain number of years have measured it as

$$\frac{\text{Cumulative \$ value of all defaulted bonds}}{\left(\dfrac{\text{Cumulative \$ value of all issuance}}{\times\text{ weighted avg. no. of years outstanding}}\right)}$$

Alternatively, some researchers report a cumulative annual default rate. This is done by not normalizing by the number of years. For example, a cumulative annual dollar default rate is calculated as

$$\frac{\text{Cumulative \$ value of all defaulted bonds}}{\text{Cumulative \$ value of all issuance}}$$

There have been several excellent studies of corporate bond default rates. We will not review each of these studies because the findings are similar. Here we will look at a study by Moody's that covers the period 1970 to 1994.[8] Over this 25-year period, 640 of the 4,800 issuers in the study defaulted on more than $96 billion of publicly offered long-term debt. A *default* in the Moody's study is defined as "any missed or delayed disbursement of interest and/or principal." Issuer default rates are calculated.

[7] Moody's Investors Service, "Corporate Bond Defaults and Default Rates: 1970–1994," *Moody's Special Report*, January 1995, p. 13. Different issuers within an affiliated group of companies are counted separately.

[8] Moody's Investors Service, "Corporate Bond Defaults and Default Rates: 1970–1994."

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The Moody's study found that the lower the credit rating, the greater is the probability of a corporate issuer defaulting.

There have been extensive studies focusing on default rates for speculative grade issuers. In their 2011 study, Altman and Kuehne find based on a sample of high-yield bonds outstanding over the period 1971–2010, default rates typically range between 2% and 5% with occasional spikes above 10% during periods of financial dislocation.[9]

Recovery Rates

There have been several studies that have focused on recovery rates or default loss rates for corporate debt. Measuring the amount recovered is not a simple task. The final distribution to claimants when a default occurs may consist of cash and securities. Often it is difficult to track what was received and then determine the present value of any noncash payments received.

While the empirical record is developing, we will state a few stylized facts about recovery rates and by implication default rates.[10]

- The average recovery rate of bonds across seniority levels is approximately 38%.
- The distribution of recovery rates is bimodal.
- Recovery rates are unrelated to the size of the bond issuance.
- Default rates and recovery rates are inversely correlated.
- Recovery rate is lower in an economic downturn and in a distressed industry.
- Tangible asset-intensive industries have higher recovery rates.

[9] Edward I. Altman and Brenda J. Kuehne, "Defaults and Returns in the High-Yield Bond and Distressed Market: The Year 2010 in Review and Outlook," Special Report, New York University Salomon Center, Leonard N. Stern School of Business, February 4, 2011.

[10] Dilip B. Madan, Gurdip S. Bakshi, and Frank Xiaoling Zhang. "Understanding the Role of Recovery in Default Risk Models: Empirical Comparisons and Implied Recovery Rates," FDIC CFR Working Paper No. 06; EFA 2004 Maastricht Meetings Paper No. 3584; FEDS Working Paper; AFA 20004 Meetings (September 2006). Available at SSRN: http://ssrn.com/abstract=285940 or doi:10.2139/ssrn.285940

MEDIUM-TERM NOTES

Medium-term notes (MTNs) are debt instruments that differ primarily in how they are sold to investors. Akin to a commercial paper program, they are offered continuously to institutional investors by an agent of the issuer. MTNs are registered with the Securities and Exchange Commission under Rule 415 ("shelf registration") which gives a corporation sufficient flexibility for issuing securities on a continuous basis. MTNs are also issued by non-U.S. corporations, federal agencies, supranational institutions, and sovereign governments.

One would suspect that MTNs would describe securities with intermediate maturities. However, it is a misnomer. MTNs are issued with maturities of 9 months to 30 years or even longer. For example, in 1993, Walt Disney Corporation issued bonds through its medium-term note program with a 100-year maturity a so-called century bond. MTNs can perhaps be more accurately described as highly flexible debt instruments that can easily be designed to respond to market opportunities and investor preferences.

As noted, MTNs differ in their primary distribution process. Most MTN programs have two to four agents. Through its agents, an issuer of MTNs posts offering rates over a range of maturities: for example, nine months to one year, one year to eighteen months, eighteen months to two years, and annually thereafter. Many issuers post rates as a yield spread over a Treasury security of comparable maturity.

Relatively attractive yield spreads are posted for maturities that the issuer desires to raise funds. The investment banks disseminate this offering rate information to their investor clients. When an investor expresses interest in an MTN offering, the agent contacts the issuer to obtain a confirmation of the terms of the transaction. Within a maturity range, the investor has the option of choosing the final maturity of the note sale, subject to agreement by the issuing company. The issuer will lower its posted rates once it raises the desired amount of funds at a given maturity.

Structured medium-term notes or simply *structured notes* are debt instruments coupled with a derivative position (options, forwards, futures, swaps, caps, and floors). For example, structured notes are often created with an underlying swap transaction. This "hedging swap" allows the issuer to create structured notes with interesting risk/return features desired by a swath of fixed income investors.

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KEY POINTS

- A bond's indenture includes the promises of corporate bond issuers and the rights of investors. The terms of bond issues set forth in bond indentures are always a compromise between the interests of the bond issuer and those of investors who buy bonds.
- The classification of corporate bonds by type of issuer include public utilities, transportations, industrials, banks and finance companies, and international or Yankee issues.
- The three main interest payment classifications of domestically issued corporate bonds are straight-coupon bonds (fixed-rate bonds), zero-coupon bonds, and floating-rate bonds (variable-rate bonds).
- Either real property (using a mortgage) or personal property may be pledged to offer security beyond that of the general credit standing of the issuer. In fact, the kind of security or the absence of a specific pledge of security is usually indicated by the title of a bond issue. However, the best security is a strong general credit that can repay the debt from earnings.
- A mortgage bond grants the bondholders a first-mortgage lien on substantially all its properties and as a result the issuer is able to borrow at a lower rate of interest than if the debt were unsecured.
- Some companies do not own fixed assets or other real property and so have nothing tangible on which they can give a mortgage lien to secure bondholders. To satisfy the desire of bondholders for security, they pledge stocks, notes, bonds, or whatever other kinds of obligations they own and the resulting issues are referred to as collateral trust bonds.
- Debentures not secured by a specific pledge of designated property and therefore bondholders have the claim of general creditors on all assets of the issuer not pledged specifically to secure other debt. Moreover, debenture bondholders have a claim on pledged assets to the extent that these assets have value greater than necessary to satisfy secured creditors. In fact, if there are no pledged assets and no secured creditors, debenture bondholders have first claim on all assets along with other general creditors.
- Owners of subordinated debenture bonds stand last in line among creditors when an issuer fails financially.
- For a guaranteed bond there is a third party guaranteeing the debt but that does not mean a bond issue is free of default risk. The safety of a guaranteed bond depends on the financial capability of the guarantor to satisfy the terms of the guarantee, as well as the financial capability of the issuer.
- Debt retirement mechanisms included in a bond's indenture are call and refunding provisions, sinking funds, maintenance and replacement funds, redemption through sale of assets, and tender offers.
- All corporate bonds are exposed to credit risk, which includes credit default risk and credit-spread risk.
- Credit ratings can and do change over time and this information is captured in a rating transition table, also called a rating migration table.
- Credit-spread risk is the risk of financial loss or the underperformance of a portfolio resulting from changes in the level of credit spreads used in the marking to market of a fixed income product. One method used commonly to measure credit-spread risk is spread duration which is the approximate percentage change in a bond's price for a 100 basis point change in the credit-spread assuming that the Treasury rate is unchanged.
- The three types of issuers that comprise the less-than-investment-grade high-yield corporate bond category are original issuers, fallen angels, and restructuring and leveraged buyouts.
- Often actions taken by management that result in the assignment of a noninvestment-grade bond rating result in a heavy interest payment burden. To reduce this burden, firms involved with heavy debt burdens have issued bonds with deferred coupon structures that permit the issuer to avoid using cash to make interest payments for a period of three to seven years. There are three types of deferred-coupon structures: deferred-interest bonds, step-up bonds, and payment-in-kind bonds.
- From an investment perspective, default rates by themselves are not of paramount significance because a portfolio of bonds could suffer defaults and still

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outperform Treasuries at the same time. This can occur if the yield spread of the portfolio is sufficiently high to offset the losses from default. Furthermore, because holders of defaulted bonds typically recover some percentage of the face amount of their investment, the default loss rate is substantially lower than the default rate. Therefore, it is important to look at default loss rates or, equivalently, recovery rates.

- A default rate can be measured in term of the issuer default rate and the dollar default rate.

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Mortgages and Mortgage-Backed Securities

21

Learning Objectives

After completing this reading you should be able to:

- Describe the various types of residential mortgage products.
- Calculate a fixed rate mortgage payment and its principal and interest components.
- Describe the mortgage prepayment option and the factors that influence prepayments.
- Summarize the securitization process of mortgage backed securities (MBS), particularly formation of mortgage pools including specific pools and TBAs.
- Calculate weighted average coupon, weighted average maturity, and conditional prepayment rate (CPR) for a mortgage pool.
- Describe a dollar roll transaction and how to value a dollar roll.
- Explain prepayment modeling and its four components: refinancing, turnover, defaults, and curtailments.
- Describe the steps in valuing an MBS using Monte Carlo Simulation.
- Define Option Adjusted Spread (OAS), and explain its challenges and its uses.

Excerpt is Chapter 20 of Fixed Income Securities: Tools for Today's Markets, *Third Edition, by Bruce Tuckman and Angel Serrat.*

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This chapter describes mortgage loans and mortgage-backed securities (MBS), presents the most popular methods used for valuation and hedging, and illustrates how prices behave as a function of the relevant variables.

MORTGAGE LOANS

Mortgage loans come in many different varieties. They can carry fixed or variable rates of interest and they can be extended for residential or commercial purposes. This chapter will focus almost exclusively on fixed rate residential mortgages. Residential mortgages typically mature in 15 or 30 years and constitute 80% of the total principal of securitized mortgages in the United States.

Given the importance of the securitization process, which will be discussed ahead, residential loans are typically classified by how they might be subsequently securitized. *Agency* or *conforming* loans are eligible to be securitized by such entities as Federal National Mortgage Association (FNMA), Federal Home Loan Mortgage Corporation (FHLMC), or Government National Mortgage Association (GNMA). The exact criteria vary by program, but these loans are relatively creditworthy[1] and limited in principal amount.

Non-agency or non-conforming loans have to be part of *private-label* securitizations. The relevant loan types include *jumbos*, which are larger in notional than conforming loans but otherwise similar; *Alt-A*, which deviate from conforming loans in one requirement; and *subprime*, which deviate from conforming loans in several dimensions. About 80% of subprime loans are *adjustable-rate mortgages (ARMs)*.

Given the role of subprime mortgages at the start of the 2007–2009 financial crisis, some further comment is in order. Borrowing and lending in the subprime market revolved around the following strategy. A relatively low-credit borrower would take out an ARM that carried a particularly low initial rate, called a *teaser*, which would reset higher after two or three years. In that time, however, should the credit of the borrower improve or should housing prices increase, the borrower would be able to pay off that first mortgage and borrow through a subsequent mortgage at a fixed rate that would have been unattainable at the start. This strategy worked well until the peak of housing prices in 2006. In fact, most subprime mortgage originations occurred between 2004 and 2006. In any case, the subsequent decline in housing prices and the resetting of ARMs to higher rates led to a significant number of defaults: by May 2008 the delinquency rate for ARMs reached 25%. The resulting foreclosures put further downward pressure on housing prices. By September 2008, the average home price had declined 20% from its 2006 peak. By September 2009, about 14.4% of all U.S. mortgages were either delinquent or in foreclosure, and, in 2009–2010, between 4% and 5% of the total number of mortgages ended in repossessions. Finally, by September 2010, principal balance exceeded home price for 23% of mortgages outstanding, with the percentages in the worst-performing real estate markets even worse (e.g., California at 32.8% and Florida at 46.4%).[2]

Fixed Rate Mortgage Payments

The most typical mortgage loan is a fixed rate, *level payment* mortgage. A homeowner might borrow $100,000 from a bank at 4% and agree to make payments of $477.42 every month for 30 years. The mortgage rate and the monthly payment are related by the following equation:

$$\$477.42 \sum_{n=1}^{360} \frac{1}{\left(1+\frac{.04}{12}\right)^n} = \$100{,}000 \qquad (21.1)$$

In words, the mortgage loan is fair in the sense that the present value of the monthly mortgage payments, discounted at the monthly compounded mortgage rate, equals the original amount borrowed. In general, for a monthly payment X on a T-year mortgage with a mortgage rate y and an original principal amount or loan balance of $B(0)$,

[1] Typical criteria would be a Fair Isaac Corporation (FICO) score greater than 660, a loan-to-value ratio of less than 80%, and full documentation of three years of income. FICO scores and loan-to-value ratios are described in subsequent footnotes.

[2] *Source:* Wells Fargo.

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$$X\sum_{n=1}^{12T}\frac{1}{\left(1+\frac{y}{12}\right)^n} = B(0)$$

$$X\frac{12}{y}\left[1-\frac{1}{\left(1+\frac{y}{12}\right)^{12T}}\right] = B(0) \qquad (21.2)$$

which can be solved for X given y directly or y given X numerically as needed. Note that the second line of (19.2) uses the summation formula.

The fixed monthly payment is often divided into its interest and principal components, a division interesting in its own right as well as for tax purposes; mortgage interest payments are deductible from income tax while principal payments are not. Letting $B(n)$ be the principal amount outstanding after the mortgage payment due on date n, the interest component on the payment on date $n + 1$ is

$$B(n) \times \frac{y}{12} \qquad (21.3)$$

In words, the monthly interest payment over a particular period equals the mortgage rate times the principal outstanding at the beginning of that period. The principal component of the monthly payment is the remainder, that is,

$$X - B(n) \times \frac{y}{12} \qquad (21.4)$$

In the example, the original balance is $100,000. At the end of the first month, interest at 4% is due on this balance, which comes to $100,000 × .04 or $333.33. The rest of the monthly payment, $477.42 − $333.33 or $144.08, is payment of principal. This $144.08 principal payment reduces the outstanding balance from the original $100,000 to $100,000 − $144.08 or $99,855.92 at the end of the first month. Then, the interest payment due at the end of the second month is based on the principal amount outstanding at the end of the first month, etc. Continuing in this way produces an *amortization table*, the first few rows of which are given in Table 21-1.

Figure 21-1 graphs the interest and principal components from the full amortization table of this mortgage. The height of each bar is the full monthly payment of $477.42, the darkly shaded height is the interest component, and the lightly shaded height is the principal component. Early payments are composed mostly of interest while later payments are composed mostly of principal. This is explained by the phrase "interest lives off principal." Interest at any time is due only on the then outstanding principal amount. As principal is paid off, the amount of interest necessarily declines.

TABLE 21-1 First Rows of an Amortization Table, in Dollars, of a 100,000 Dollar 4% 30-Year Mortgage

Payment Month	Interest Payment	Principal Payment	Ending Balance
			100,000.00
1	333.33	144.08	99,855.92
2	332.85	144.56	99,711.36
3	332.37	145.04	99,566.31
4	331.89	145.53	99,420.78
5	331.40	146.01	99,274.77

While the outstanding balance of a mortgage on any date can be computed through an amortization table, there is an instructive shortcut. Discounting using the mortgage rate at origination, the present value of the remaining payments equals the principal outstanding. This is a fair pricing condition under the assumptions that the term structure is flat and that interest rates have not changed since the origination of the mortgage.

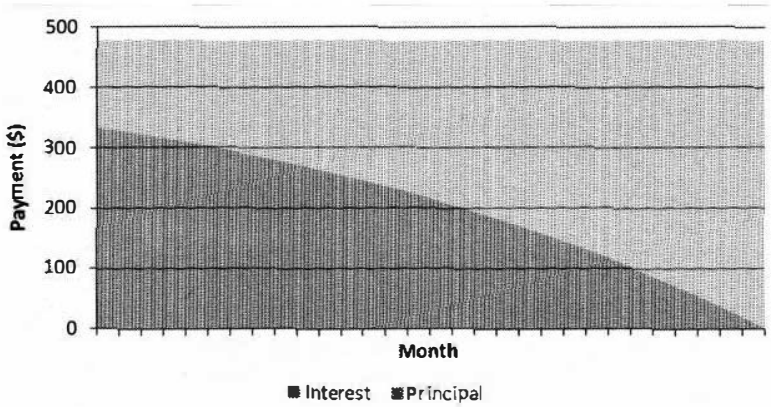

FIGURE 21-1 Amortization of a $100,000 4% 30-year mortgage.

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To illustrate this shortcut in this example, after 5 years or 60 monthly payments there remain 300 payments. The present value of these payments at the mortgage rate of 4% is

$$\$477.42\sum_{n=1}^{300}\frac{1}{\left(1+\frac{.04}{12}\right)^{n}} = \$477.42\frac{12}{.04}\left[1-\frac{1}{\left(1+\frac{.04}{12}\right)^{300}}\right] = \$90{,}448 \tag{21.5}$$

Hence, the scheduled principal amount outstanding after five years is also $90,448.

This section describes the market convention of calculating the mortgage payment from a single mortgage rate or *vice versa*. This in no way contradicts the fact that the market values mortgages using an appropriate term structure of rates and spreads.

If rates or spreads rise after origination, the present value of the remaining mortgage payments will be worth less than the outstanding principal amount while, if rates fall, this present value will exceed the outstanding principal amount. The value of a mortgage, however, is not simply the present value of its payments because of the borrower's prepayment option, which is introduced in the next subsection.

The Prepayment Option

Mortgage borrowers have a *prepayment option*, that is, the option to pay the lender the outstanding principal at any time and be freed of the obligation to make further payments. In the example of the previous subsection, the mortgage balance at the end of five years is $90,448. At that time, therefore, the borrower can pay the lender this balance and no longer have to make monthly payments.

The prepayment option is valuable when mortgage rates have fallen. In that case, as mentioned previously, the present value of the remaining monthly payments exceeds the principal outstanding. Therefore, the borrower gains in present value from paying the principal outstanding in exchange for not having to make further payments. When rates have risen, however, the present value of the remaining payments is less than the principal outstanding and prepayment would result in a loss of present value. By this logic, the prepayment option is an American call option on an otherwise identical, (fictional) nonprepayable mortgage. The strike of the option is the principal amount outstanding and, therefore, changes after every payment.

When pricing the embedded options in bonds issued by government agencies or corporations, it is reasonable to assume that a relatively efficient call policy will prevail. In terms of a term structure model, an efficient call policy means that an issuer will exercise a call option if and only if the value of immediately exercising the option exceeds the value of holding the option. If the mortgage borrowers faced as simple an optimization problem, so that their prepayments were as easily predictable, mortgages could be valued using term structure models. However, prepayments of mortgages turn out to be much more difficult to model, which is discussed later in this chapter.

While the prepayment option refers to the choice borrowers can make to return outstanding principal, the term prepayment refers to any return of principal above the amount scheduled to be returned by the amortization table. When a mortgage borrower sells a property, for example, the principal becomes due no matter what the level of interest rates. Hence, to value mortgages, prepayment models have to consider all forms of prepayments.

MORTGAGE-BACKED SECURITIES

Until the 1970s banks made mortgage loans and held them until maturity, collecting principal and interest payments until the mortgages were repaid. The primary market was the only mortgage market. During the 1970s, the *securitization* of mortgages began. The growth of this secondary market substantially changed the mortgage business. Banks that might have had to restrict mortgage lending, either because of limited capital or risk appetite, could now continue to make mortgage loans since these loans could be quickly and efficiently sold. At the same time, investors gained a new security type through which to lend their surplus funds. Of course, one of the policy questions raised by the 2007–2009 financial crisis was whether the mortgage securitization process, for any of several reasons, had created too much systemic risk.

Issuers of MBS gather mortgage loans into *pools* and then sell claims on those pools to investors. In the simplest structure, a *mortgage pass-through*, the cash flows from the underlying mortgages, that is, interest, scheduled principal, and prepayments, are passed from the borrowers to the investors with some short processing delay. *Mortgage servicers* manage the flow of cash from borrowers to investors in exchange for a fee taken from those cash flows. *Mortgage guarantors* guarantee investors the payment of interest and principal against borrower defaults, also in exchange for a fee. When a borrower does

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default, the guarantor compensates the pool with a lump-sum payment and then, through the servicer, pursues the borrower and the underlying property to recover as much of the amount paid as possible. By the way, in comparison with U.S. lenders, European lenders have easier recourse to borrower assets that are not part of the mortgaged property.

The Overview reported that U.S. mortgage debt was a little over $14 trillion in 2010. Of this total, $7.5 trillion had been securitized. This securitized amount is further subdivided into $5.4 trillion of *agency securities*, i.e., securities guaranteed or issued by such entities as GNMA, FNMA, and FHLMC, and the remainder *private-label* securities issued by private financial institutions. These amounts outstanding are misleading, however, with respect to new issuance. Since the 2007–2009 crisis to the time of this writing, agency securities comprised almost all of new MBS issuance.

Mortgage Pools

Loans that are collected into a pool are usually similar with respect to loan type, mortgage rate, and date of origination. Table 21-2 gives some summary statistics, both at origination and as of December 2010, of a pool of 30-year loans issued by FNMA in January 2005 of loans originated in 2004, i.e., of the 2004 "vintage." The coupon of the pool, that is, the rate paid to investors, is 3.5%. According to the table, the pool was issued with 91 loans and a total principal amount of about $13.6 million. The table next reports two weighted averages, where the weighting is based on loan size. The *weighted-average coupon* or *WAC* is the weighted average of the mortgage rates of the loans and was 3.94% at issuance. Note that, as a weighted average of loan rates, the term WAC somewhat confusingly uses the word "coupon." It is best to think of there being only one "coupon" rate, namely the interest rate on the pool as a whole that is passed on to investors. In any case, returning to the pool of Table 21-2, note that the 3.5% coupon is less than the 3.94% original WAC: the difference between what the borrowers pay and what the investors receive is paid to the servicer and to the guarantor. Finally, the *weighted-average maturity (WAM)* of the loans was 335 months. This original WAM on a pool of "30-year" loans means that some of the loans were slightly seasoned (i.e., had been outstanding for some amount of time) when the pool was issued.

TABLE 21-2 Summary Statistics for FNMA Pool FG A47828, 3.5% 2004 Vintage at Origination and as of December 2010

	Original	Dec 2010
Number of Loans	91	69
Principal Amount	$13,635,953	$9,326,596
WAC	3.940%	3.928%
WAM (months)	335	271

Source: Bloomberg.

The summary statistics of the FNMA 3.5% 2004 pool as of December 2010 show that a significant fraction of the pool has paid down. The pool's *factor* is the ratio of the current to the original principal amount outstanding, which in this case is about 68%. A good deal of this is due to prepayments rather than scheduled amortization. First, although the principal amount of each loan is not provided here, only 69 of the original 91 loans are still in the pool. Second, for an order of magnitude calculation, Equation (21.5) calculated that the scheduled principal outstanding of a 4% 30-year loan after five years is a little over 90% of the original principal amount. The WAC here is slightly less than 4% and the pool is not exactly five years old, but the factor of 68% is significantly below 90%. Note that the WAC of the pool has fallen very slightly since origination, indicating that prepaying loans had slightly higher rates than loans remaining in the pool. Finally, the WAM has fallen by 64 months or a bit over five years, indicative mostly of the loans aging five years from issuance at the end of 2004 to December 2010.

While coupon and age are the most important characteristics of loans and pools with respect to pricing, other characteristics are important as well, as will be discussed further in the section on modeling prepayments. As a result, issuers of MBS provide pool summary statistics on characteristics other than those listed in Table 21-2. Examples include FICO scores,[3] loan-to-value (LTV) ratios,[4] and the geographical distribution of the loans. For the FNMA 3.5% 2004 pool, it happens that 100% of the loans are in New Jersey.

[3] FICO scores, a product of Fair Isaac Corporation, measure a borrower's ability to pay based on credit history. The scores range from 300 to 850, with a score above 650 considered creditworthy by many lenders.

[4] The LTV ratio is the principal amount of the loan divided by the value of the mortgaged property.

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TABLE 21-3 Agency Pool Issuance, in Billions of Dollars

	2010						Full Year		
	Dec*	Nov	Oct	Sep	Aug	Jul	2010*	2009	2008
Total	72	146	143	141	111	107	1,312	1,725	1,153
Issuer									
FHLMC	21.6	38.6	37.4	36.4	28.4	26.6	351	462	341
FNMA	42.0	73.5	69.8	70.6	48.0	42.9	586	806	541
GNMA1	8.0	14.9	16.0	13.4	12.2	13.4	156	288	146
GNMA2	.6	19.3	19.5	20.3	22.0	24.5	219	169	125
Loan Type									
30-Year	56.1	103	100	103	79.2	79.6	973	1,449	951
15-Year	11.9	25.3	24.7	21.7	15.3	13.4	187	181	93
ARM	1.6	7.1	6.8	4.9	6.8	8.0	67	33	78
Other	2.5	10.9	11.2	10.9	9.4	6.4	85	62	32
Coupon									
<4%	8.4	12.4	11.0	4.6	1.2	.5	40	3	0
4%–	35.6	63.1	59.6	51.0	16.0	7.8	250	211	0
4.5%–	9.2	20.9	24.0	39.7	45.7	46.0	428	715	18
5%–	2.2	5.1	4.5	6.5	14.6	23.5	233	375	201
>5%	.7	1.3	1.0	1.4	1.8	1.7	23	145	731

*To Dec10.

Source: Bloomberg.

Table 21-3 shows the issuance volumes of agency pools for the full years 2008, 2009, and 2010, along with monthly issuance for the second half of 2010. These volumes are also broken down by issuer, loan type, and coupon. Total issuance fell dramatically in 2010 relative to 2009, reflecting lower volumes of real estate transactions. Furthermore, the increase from 2008 to 2009 is in part due to the shift from private label to agency issuance mentioned earlier. The issuer breakdown reveals that FNMA is the largest issuer, and the breakdown by loan type reveals the dominance of the 30-year mortgage. Mortgage loans, and therefore pools, are issued at prevailing market rates, that is the rates that make them sell for approximately par. Thus, the shift of dominant volume from the >5% bucket in 2008, to the 4.5%–5% bucket in 2009, to the 4% bucket in September 2010, simply reflects the fall in mortgage rates, and interest rates generally, over this time period.

Calculating Prepayment Rates for Pools

In any given month, some loans in a pool will prepay completely, some will not prepay at all, and some—usually a small number—may *curtail*, i.e., partially prepay. For the purposes of valuation it is conventional to measure the principal amount prepaying as a percentage of the total principal outstanding. The *single monthly*

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mortality rate at month n, denoted SMM_n, is the percentage of principal outstanding at the beginning of month n that is prepaid during month n, where prepayments do not include scheduled, i.e., amortizing, principal amounts. The SMM is often annualized to a *constant prepayment rate or conditional prepayment rate* (CPR). A pool that prepays at a constant rate equal to SMM_n has $1-SMM_n$ of the principal remaining at the end of one month, $(1 - SMM_n)^{12}$ remaining at the end of 12 months, and, therefore, $1 - (1 - SMM_n)^{12}$ principal prepaying over those 12 months. Hence, the annualized CPR is related to SMM as follows:

$$CPR_n = 1 - \left(1 - SMM_n\right)^{12} \tag{21.6}$$

For example, if a pool prepaid .5% of its principal above its amortizing principal in a given month, it would be prepaying that month at a CPR of about 5.8%. Note that a pool has a CPR every month even though CPR is an annualized rate.

Specific Pools and TBAs

Agency mortgage pools trade in two forms: *specified pools* and TBAs. The latter is an acronym for *To Be Announced* and only the acronym is used by practitioners.

In the specified pools market, buyers and sellers agree to trade a particular pool of loans. Consequently, the price of a trade reflects the characteristics of the particular pool. For example, the next section of this chapter will argue that pools with relatively high loan balances are worth less to investors because these pools make relatively better use of their prepayment options. Therefore, in the specified pools market, relatively high loan-balance pools will trade for relatively low prices.

Much more liquid, however, is the TBA market, which is a forward market with a delivery option. Table 21-4 gives bid prices for selected FNMA 30-year TBAs as of December 10, 2010. Consider a trade on that date of $100 million face amount of the FNMA 5% 30-year TBA for February delivery at a price of 104–09. Come February the seller chooses a 30-year 5% FNMA pool and delivers $100 million face amount of that pool to the buyer for 104–09. Just as in the case of the delivery option in note and bond futures, the TBA seller will pick the cheapest-to-deliver (CTD) pool, that is, the pool that is worth the least subject to the issuer, maturity, and coupon requirements. For example, following up on the remark in the previous paragraph that pools with high loan balances are less valuable than other pools, the TBA seller might wind up delivering a pool with particularly high loan balances. In any case, *ex-ante*, TBA prices will reflect the fact that the CTD pools will be delivered. In fact, specified pools trade at a reference TBA price plus a *pay-up* that depends on the specified pools' characteristics *versus* those of the pools likely to be delivered.

TABLE 21-4 Bid Prices for Selected FNMA 30-Year TBAs as of December 10, 2010. Fractional prices are in 32nds; a "+" is half a 32nd or a 64th.

	4%	4.5%	5%
Jan	98 – 30+	101 – 31+	104 – 15+
Feb	98 – 21	101 – 22	104 – 09
Mar	98 – 10+	101 – 12	104 – 01

Source: Bloomberg.

As the TBA market is so liquid, especially the front contracts that trade near par, there is particular focus in the broader mortgage market on the contract that trades closest to, but below par. This contract is called the *current contract* and its coupon the *current coupon.* In Table 21-4, since the prices of the 4% and 4.5% January TBAs bracket par, 4% would be the current coupon. Furthermore, the term *current mortgage rate* is sometimes used to refer to the interpolated coupon at which a front TBA would sell for par.[5] Using the prices in Table 21-4 for this purpose, the current mortgage rate would be about 4.17%.

While the TBA market is much more liquid than the specified pools market, the latter has grown rapidly in recent years. First, episodes in which the delivery option was particularly valuable have made traders and investors increasingly aware of the risks posed by the delivery option. Second, agencies have been supplying increasing amounts of granular data about the characteristics of loans in pools, which allows for more effective specified pools trading.

Dollar Rolls

Consider an investor who has just purchased a mortgage pool but wants to finance that purchase over the next

[5] The term "current mortgage rate" is also used to refer to the rate borrowers pay on newly originated mortgages.

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month. One alternative is an MBS repo. The investor could sell the repo, i.e., sell the pool today while simultaneously agreeing to repurchase it after a month. This trade has the same economics as a secured loan: the investor effectively borrows cash today by posting the pool as collateral, and, upon paying back the loan with interest after a month, retrieves the collateral.

An alternative for financing mortgages is the *dollar roll.* The *buyer of the roll* sells a TBA for one settlement month and buys the same TBA for the following settlement month. For example, the investor who just purchased a 30-year 4% FNMA pool might sell the FNMA 30-year 4% January TBA and buy the FNMA 30-year 4% February TBA. Delivering the pool just purchased through the sale of the January TBA, which raises cash, and purchasing a pool through the February TBA, which returns cash, is very close to the economics of a secured loan. There are, however, two important differences between dollar roll and repo financing.

First, the buyer of the roll may not get back in the later month the same pool delivered in the earlier month. In the example, the buyer of the Jan/Feb roll delivers a particular pool in January but will have to accept whatever eligible pool is delivered in February. By contrast, an MBS repo seller is always returned the same pool that was originally posted as collateral.

Second, the buyer of the roll does not receive any interest or principal payments from the pool over the roll. In the example, the buyer of the Jan/Feb roll, who delivers the pool in January, does not receive the January payments of interest and principal.[6] By contrast, a rep a seller receives any payments of interest and principal over the life of the repo. While the prices of TBA contracts reflect the timing of payments, so that the buyer of a roll does not, in any sense, lose a month of payments relative to a repo seller, the risks of the two transactions are different. The buyer of a roll does not have any exposure to prepayments over the month being higher or lower than what had been implied by TBA prices while the repo seller does.

The forward drop is the difference between a spot and forward price. The forward price is usually below the spot price because buying a security forward sacrifices the relatively high rate of interest earned on the security in exchange for the relatively low, short-term rate of interest earned by investing the funds that would have gone into the spot purchase. Put another way, the forward price is determined such that investors are indifferent between buying a security forward and buying it spot. In an important sense, the same reasoning applies to TBA prices and the roll: prices of pools for later delivery tend to be lower because pools earn a higher rate of interest than the short-term rate. Note how this rule characterizes the prices in Table 21-4. Once again, however, the TBA delivery option complicates the analysis. Consider the Jan/Feb roll as of January. If the delivery option had no value, the forward price for February would be determined along the lines of Chapter 5 of this book and investors would be indifferent between: (1) buying the pool and the roll, which is essentially buying a pool forward for February delivery; and (2) buying a pool and holding it from January to February. But if the delivery option has value, the February TBA price would be lower and the forward drop would be larger than it would be otherwise.

In market jargon, the *value of the roll* is the difference in proceeds between (1) starting with a given pool and buying the roll and (2) holding that pool over the month. If the value of the roll is zero, the roll is said to trade at *breakeven.* If the forward drop is larger so that the value of the roll is positive, the roll is said to trade *above carry.* Given the delivery option of TBAs, the roll would be expected to trade somewhat above carry without necessarily implying a value opportunity.

To make the roll more concrete, consider the following example. Suppose that the TBA prices of the Fannie Mae 5% for July 12 and August 12 settlements are $102.50 and $102.15, respectively. The accrued interest to be added to each of these prices is 12 actual/360 days of a month's worth of a 5% coupon, i.e., 100 × (12/30) × 5%/12 or .167. Let the expected total principal paydown, that is, scheduled principal plus prepayments, be 2% of outstanding balance and let the appropriate short-term rate be 1%.

If an investor rolls a balance of $10 million, proceeds from selling the July TBA are $10mm × (102.50 + .167)/100 or $10,266,700. Investing these proceeds to August 12 at 1% earns interest of $10,266,700 × (31/360) × 1% or $8,841. Then, purchasing the August TBA, which has experienced a 2% principal paydown, costs $10mm × (1 − 2%) × (102.15 + .167)/100 or $10,027,066. The net proceeds

[6] The record date for MBS is usually the last day of the month while pools delivered through TBA settle on the 15th or 25th of the month depending on the underlying issuer.

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from the role, therefore, are $10,266,700 + $8,841 − $10,027,066 or $248,475.

If the investor does not roll, the net proceeds are the coupon plus principal paydown, i.e., $10mm × (5%/12 + 2%) or $241,667.

In conclusion, then, the roll is trading above carry in this example, with the value of the roll at $248,475 − $241,667 or $6,808.

Other Products

This chapter focuses on pass-through MBS, but a few other products will also be mentioned.

The properties of pass-through securities do not suit the needs of all investors. In an effort to broaden the appeal of MBS, practitioners have carved up pools of mortgages into different derivatives. One example is *planned amortization class (PAC)* bonds, which are a type of *collateralized mortgage obligation (CMO)*. A PAC bond is created by setting some fixed prepayment schedule and promising that the PAC bond will receive interest and principal according to that schedule so long as the actual prepayments from the underlying mortgage pools are not exceptionally large or small. In order to fulfill this promise, other derivative securities, called *companion* or *support* bonds, absorb the prepayment uncertainty. If prepayments are relatively high and PAC bonds receive their promised principal payments, then the companion bonds must receive relatively large prepayments. Alternatively, if prepayments are relatively low and PAC bonds receive the promised principal payments, then the companion bonds must receive relatively few prepayments. The point of this structure is that investors who do not like prepayment uncertainty can participate in the mortgage market through PACs. Dealers and investors who are comfortable with modeling prepayments and with controlling the accompanying interest rate risk can buy the companion or support bonds.

Other popular mortgage derivatives are *interest-only (IO)* and *principal-only (PO)* strips. The cash flows from a pool of mortgages are divided such that the IO gets all the interest payments while the PO gets all the principal payments. The unusual price rate behavior of these mortgage derivatives is illustrated later in this chapter.

Constant maturity mortgage (CMM) products allow investors to trade mortgage rates directly as a convexity-free alternative to trading prices of MBS that depend on mortgage rates. A CMM index is constructed from 30-year TBA prices to be the hypothetical coupon on a TBA for settlement in 30 days that trades at par. Market participants trade CMM mostly through Forward Rate Agreements (FRAs).

Mortgage options are calls and puts on TBAs. The most liquid options are written on TBAs with delivery dates in the next three months.

PREPAYMENT MODELING

Earlier in this chapter it was noted that the prepayment option is not as simply modeled as are the contingent claims priced using term structure models. Part of the reason for this is that some sources of prepayments are not determined exclusively or even predominantly by interest rates, e.g., selling a home to buy a bigger or smaller one, divorce, default, and natural disasters that destroy a property. Another reason is that the cost of focusing on the prepayment problem, of figuring out the best action to take, and of navigating the process through financial institutions can be quite large. In any case, just because prepayments cannot be predicted by a simple optimization model does not mean that they are suboptimal from the point of view of mortgage borrowers. In any case, with the optimization problem across borrowers so difficult to specify, prepayment modeling relies heavily on empirical estimation of observed behavior.

A prepayment model uses loan characteristics and the economic environment (i.e., interest rates and sometimes housing prices) to predict prepayments. The most common practice identifies four components of prepayments, namely, in order of importance, *refinancing*, *turnover*, *defaults*, and *curtailments*. These components are typically modeled separately and their parameters estimated or calibrated so as to approximate available historical data.

Refinancing

In a refinancing a borrower pays off the principal of an existing mortgage with the proceeds of a new one. One major motive of refinancing is to reduce cost. A refinancing saves the borrower money if the rate on an available new mortgage has declined sufficiently relative to the rate on the existing mortgage and the transaction costs of refinancing. The most likely reason for a decline in the mortgage rate is that the general level of interest rates

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has declined. But there are other reasons as well: the spread of mortgage rates over benchmark rates has declined; the borrower's credit rating has improved; or the value of the mortgaged property has increased. Another important motive of refinancing is to extract home equity. If a property value has increased, a borrower might take out a new mortgage with a higher balance than that on the existing mortgage so as to payoff that existing mortgage and have cash remaining for other purposes. This is known as a *cash-out refinancing* and was used extensively in the run-up to the 2007–2009 crisis.

Modeling the refinancing component of prepayments often starts with an *incentive function* for a pool or group of loans in a pool and then defines prepayments due to refinancing as a nondecreasing function of that incentive. A simple example of an incentive might be

$$I = (WAC - R) \times WALS \times A - K \qquad (21.7)$$

where *WAC* is the weighted average coupon of the pool, *R* is the current mortgage rate available to borrowers,[7] *WALS* is the weighted-average loan size of the pool, *A* is an annuity factor that gives the present value of an annual dollar payment from the average loan (i.e., from a loan with a remaining maturity equal to the average maturity of the loans being modeled), and *K* is an estimate of the fixed cost of refinancing. The current mortgage rate is actually lagged by a month or two in an incentive function to reflect lags in initiating and processing a refinancing application.

The logic of the incentive function (19.7) is that it estimates the present value of the dollar gains to the borrower from refinancing. Refinancing reduces the mortgage rate by *WAC* − *R* on a principal amount of *WALS*. Then, to get the present value of this reduction, multiply by the appropriate annuity factor. Lastly, subtract the fixed cost of refinancing to get the net present value of refinancing. This theoretical argument in support of having incentive increase with loan size is quite persuasive, but the proposition is supported by empirical evidence as well. Average loan balances decline as pools age, indicating that loans with higher balances prepay more quickly. For orders of magnitude, average loan balances in newly issued agency pools are typically larger than $175,000 but can be smaller than $80,000 for older pools.

[7] The Primary Mortgage Market Survey Rate, published weekly by FHLMC, is often used to represent the mortgage rate available to borrowers for conforming loans.

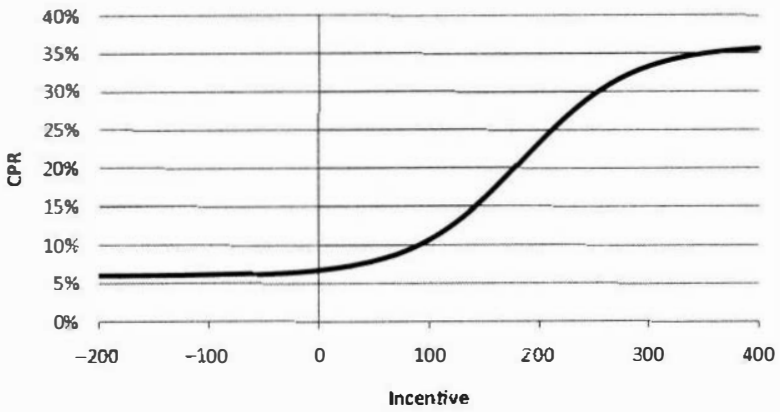

FIGURE 21-2 An example of *S*-curve prepayments as a function of Incentive.

Having specified the incentive, prepayments, measured in terms of *CPR*, are typically modeled as an *S*-curve of that incentive. One example of such a function is

$$CPR(I) = T + \frac{1}{a + e^{-bI}} \qquad (21.8)$$

where *T* is turnover, discussed in the next subsection, and *a* and *b* are parameters that are calibrated to fit the empirical prepayment behavior of pools, or groups of loans within pools, that are similar to the mortgages being modeled. Figure 21-2 graphs the function (19.8) with an incentive measured simply as the difference between the *WAC* and the current mortgage rate available to borrowers. The generic shape of the *S*-curve is popular since it reflects the empirical behavior that prepayments eventually flatten for very low (negative) and very high incentives.

To capture the complex behavior of actual prepayments the parameters *a* and *b* have to vary across loan types and also have to be functions of loan characteristics and the economic environment within loan types. There are very many examples. Since borrowers with relatively high creditworthiness prepay relatively quickly for a given incentive, parameters are made to depend on some proxy for credit, e.g.: *spread at origination (SATO)*, which is *WAC* or mortgage coupon relative to current coupon at origination; original FICO; or original LTV. Since higher home prices make it easier for homeowners to refinance, parameters can depend on general or local measures of home price appreciation since origination, to the extent these data are available. Another example is having parameters vary by state or locality to reflect observed differences in prepayment behavior across geographic regions.

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An additional and extremely important reason that the parameters a and *b* cannot be constant is so that the prepayment function (19.8) can model *burnout*. Figure 21-3 shows a time series for the monthly CPR for the FNMA 30-year 7% 1995 along with the current coupon as a proxy for the mortgage rate faced by borrowers. The very broad story of the figure is consistent with prepayments increasing with incentive. For example, as the mortgage rate fell from 8% in the beginning of 2000 to less than 4.5% in spring 2003, CPR increased and peaked at over 60%. But there is another story at work in the figure. When this 1995 vintage pool first experienced mortgage rates of between 6% and 6.50%, in fall 1998, CPR peaked at over 40%. But when the mortgage rate was between 6% and 6.50% in 2006 and 2007, average CPR was much lower. Similarly, CPR peaked at 60% when the mortgage rate was around 4.5% to 5.5%, but with rates below 4.5% after early 2009, CPR was mostly in the range of 10% to 15%. Finally, with mortgage rates eventually falling to historic lows of less than 3.5%, CPR essentially remained in that 10% to 15% range.

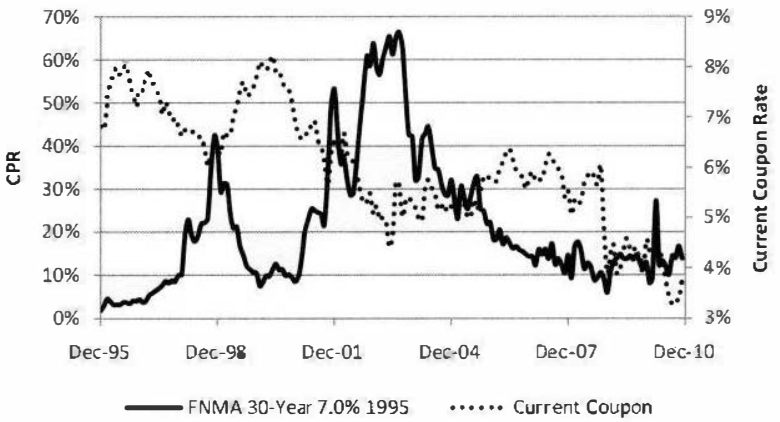

FIGURE 21-3 CPR of the FNMA 30-Year 7.0% 1995 and the current coupon.

To explain the prepayment behavior just described, think about each borrower in the pool as having some set of characteristics that determines a propensity to prepay for a given incentive. For example, a financially sophisticated borrower with a relatively high credit rating, a large loan balance, and a home that has appreciated in price will be the most likely to refinance as mortgage rates decline. In terms of Figure 21-3, this borrower most probably refinanced when rates fell to between 6% and 6.50% in fall 1998. From then on, however, this and other borrowers who are most likely to prepay are no longer in the pool. Therefore, with rates in that same 6% to 6.50% range at a later date, like the period in 2006 and 2007 in the figure, prepayments will be determined by borrowers with a lower propensity to refinance and, therefore, CPR will be lower. The phenomenon of CPR being less responsive to incentive as a pool prepays is known as burnout. In terms of the prepayment model (19.8), capturing burnout requires that the parameters be a function of past levels of prepayment rates or mortgage rates.

To mention one more example of how complex models of refinancing can be, researchers have posited a *media effect*, in which a precipitous decline in mortgage rates or mortgage rates reaching a new low creates media reports and cocktail-party conversation that encourage even those borrowers with relatively low propensities to refinance to do so. Capturing this phenomenon in a model would require its parameters to depend on carefully chosen summary statistics that describe the historical path of mortgage rates, e.g., the current mortgage rate relative to the lowest mortgage rate over the last five years.

Turnover

Prepayments due to turnover occur when borrowers sell houses to relocate, to change to a bigger or smaller house, as a result of a divorce, or in response to other personal circumstances. This driver of prepayments typically accounts for less than 10% of overall prepayment rates.

A turnover model for a particular group of loans begins with a base rate that is adjusted to account for the seasonality of relocations, e.g., higher in summer, lower in winter. The model would then add a *seasoning ramp*. Households are very unlikely to move just after taking out a mortgage. A typical average assumption would be that turnover starts at zero at the time of initiation and increases to the base rate after 30 months. The steepness of the seasoning ramp is often made to depend on several factors. For example, less creditworthy borrowers are more likely to prepay sooner after taking out a mortgage as some will experience improvements to their creditworthiness.

While prepayments classified as due to turnover are for the most part independent of interest rates, there is an interaction that cannot be ignored. Borrowers are less

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likely to move if they enjoy a below-market mortgage rate, or, put another way, if they would have to pay a higher rate on a new mortgage after selling their homes and moving. This behavior is known as the *lock-in* effect.

Defaults and Modifications

Defaults are a source of prepayments in the sense that mortgage guarantors pay interest and principal outstanding when a borrower defaults. Over the most recent cycle of increasing real estate values, modeling defaults had been less important and had received less attention. This changed dramatically, of course, in reaction to falling housing prices in the run-up to and progression of the 2007–2009 crisis. In addition, mortgage modifications, which did not exist previously, have become an important part of the landscape. From the modeling perspective, more effort is being dedicated to using pertinent variables, e.g., initial LTV ratios, FICO scores, and SATO (which are not usually updated after mortgage issuance), and to incorporating the dynamics of housing prices into the analysis.

Curtailments

Curtailments are partial prepayments by a particular borrower. These tend to be most important when loans are older and balances are low. This driver of prepayments is modeled as a function of loan age and can, with only a couple of years remaining to maturity, rise to a CPR of about 5%.

MBS VALUATION AND TRADING

This section describes how to combine models of the benchmark interest rate with mortgage-specific model components to value MBS. As will be explained presently, while the term structure models are relevant for MBS valuation, the tree implementations of these models are not. Therefore, the section begins with an alternate implementation, namely, *Monte Carlo simulation*, to be followed by other valuation issues.

Monte Carlo Simulation

Suppose for a moment that a one-factor tree implementation of a term structure model was used to value MBS. The cash flows at any node of the tree would be determined by scheduled cash flows and the prepayment model. Then, the value of the MBS at any node would be the cash flow on that date plus the expected discounted value of the MBS on the subsequent date. The problem with this approach, however, is that it assumes that the cash flows at any node depend only on the short-term rate at that node, or, equivalently, on the term structure of interest rates at that node. But what if prepayments at particular nodes depend on the history of interest rates on the way to that node, as models of burnout require. In that case the tree implementation fails because it does not naturally recall, for example, whether a node five periods from the start was reached by two down moves followed by three up moves, by three up moves followed by two down moves, or by the sequence up-down-up-down-up. But the burnout effect says that prepayments at a particular node will be less if that node was reached by passing through a node with a relatively low interest rate. In the jargon of valuation models, the tree implementation assumes that cash flows are *path independent* while the cash flows from a burnout model are *path dependent*.

The most popular solution to pricing path-dependent claims is Monte Carlo simulation. To price a security in this framework, proceed as follows. First, generate a large number of paths of interest rates at the frequency and to the horizon desired. For this purpose paths are generated using a particular risk-neutral process for the short-term rate. Second, calculate the cash flows of the security along each path. In the mortgage context this would include the security's scheduled payments along with its prepayments. Note that burnout and media effects can be implemented because each path is available in its entirety as cash flows are calculated. Third, starting at the end of each path, calculate the discounted value of the security's cash flows along each path. Fourth, compute the value of the security as the average of the discounted values across paths.

Table 21-5 presents an extremely simple example of a 5% five-year, annually-paying mortgage pool to illustrate the process along a single path. The arrows at the top indicate that the process is moving forward in time, from date 0 to 5. The interest rate, used as the mortgage rate and as the discounting rate in this simple example, starts at 5%, is 5% at the end of the first year, 4% at the end of the second year, etc. The next rows give, per 100 of original notional, the pool's scheduled interest and principal payments

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TABLE 21-5 Example of a Single Path in the Monte Carlo Framework in the Mortgage Context

Date	0	1	2	3	4	5
Interest Rate	5%	5%	4%	3%	4%	
Starting Principal		100.00	80.00	54.00	21.70	10.79
Interest Due		5.00	4.00	2.70	1.09	0.54
Principal Due		18.10	18.56	17.13	10.59	10.79
Prepayments		1.90	7.44	15.17	0.33	0.00
Total Cash Flow		25.00	30.00	35.00	12.00	11.32
Value	100.93	80.97	55.02	22.22	10.89	11.32

based on the amount outstanding at the beginning of each period, the pool's prepayments from some model, and the total cash flows on each date. Note that the prepayment model can refer to the entire history of rates along the path when computing prepayments.

At this point the process starts from the last date and moves backwards in time. The value of the pool on date 5 is simply the cash flow paid on that date, which is 11.32. The value on date 4 is the present value of the date 5 cash flow, i.e., 11.32 $(1.04)^{-1}$ or 10.89. The value on date 3 is the present value of the date 4 value plus the date 4 cash flow, that is,

$$\frac{10.89 + 12}{1.03} = 22.22 \tag{21.9}$$

Continuing in this manner, the value of the MBS on date 0 along this path is 100.93. Having gone through this process for all of the paths, the value of the MBS is the average date 0 value across paths.

To reconcile Monte Carlo pricing with pricing using an interest rate tree, recall the equation, which, derived in the context of interest rate trees, gives the price of a claim that is worth P_n in n periods. This equation is reproduced here for convenience:

$$P_0 = E\left[\frac{P_n}{\prod_{i=0}^{n-1}(1+r_i)}\right] \tag{21.10}$$

In light of the discussion of this subsection, the term inside the brackets is analogous to the price of a security along one path. The expectation is analogous to the averaging across paths.

Two more comments will be made about the Monte Carlo framework. First, measures of interest rate sensitivity can be computed by shifting the initial term structure in some manner, repeating the valuation process, and calculating the difference between the prices after and before the interest rate shift. Second, while the Monte Carlo approach does accommodate path-dependent cash flows, it has two major drawbacks. One, it is more computationally and numerically challenging than pricing along a tree. Two, it is difficult in the Monte Carlo framework to value American- or Bermuda-style options. (Examples in the mortgage context include mortgage options, mentioned earlier, and callable CMOs.) For these options, which allow early exercise, the value of the option at each node is the maximum of the value of exercising the option immediately and the value of the option not exercised. In a tree methodology, which starts at maturity and works backwards, both of these values are available at each node. Along a Monte Carlo path, however, the value of immediate exercise is always known, but the value of the unexercised option is very difficult to compute. Starting a new Monte Carlo pricing simulation at a particular date on a particular path so as to compute the value of the unexercised option for that date and path is possible, but doing so for every exercise date on every path is not computationally feasible.

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Valuation Modules

Computing values for MBS require several modules. In no particular order, since they interact with another, these include a model of benchmark interest rates, the scheduled cash flows of the MBS, a model of the mortgage rate, a housing price model, and a prepayment model.

As described in the previous subsection, Monte Carlo implementations usually replace tree implementations. The scheduled cash flows of the MBS are straightforward, as described in the first section of this chapter.

While glossed over in the example of the previous subsection, valuing an MBS along a path requires both the benchmark or discounting rate as well as the mortgage rate; discounting might be done at swap rates plus a spread, but the incentive of a prepayment model depends on the current mortgage rate. But determining the fair mortgage rate at a single date and on a single path of a Monte Carlo valuation is a problem of the same order of magnitude as the original problem of pricing a particular MBS! Common practice, therefore, is to build a simple model of the mortgage rate as a function of the benchmark rates, e.g., as a function of the 10-year swap rate. A particularly simple approach—some say simplistic—is to use a regression of the 30-year mortgage rate on the 10-year swap rate. Note, in any case, that it may not be trivial to compute any longer-term swap rate at points along a path of short-term rates for the same reason as highlighted in the context of pricing options with early exercise. But the problem of computing swap rates can often be handled by using a closed-form solution or a numerical approximation consistent with the process generating the path of short-term rates.

A model of the evolution of housing prices can be particularly useful in modeling the default component of prepayments or prepayments more generally. The major difficulties, of course, are determining an appropriate probability distribution for housing prices and appropriate correlations for housing prices and interest rates.

Putting the modules together, cash flows are determined by the scheduled cash flows and the prepayment model. The prepayment model depends on the interest rate model, the mortgage rate model, and the housing price model. The mortgage rate model and the housing price model depend on the interest rate model. And finally, the interest rate model is used to value the cash flows.

MBS Hedge Ratios

As mentioned earlier, interest rate sensitivities and hedge ratios can be computed from MBS valuation models. Given the considerable investment required to build an MBS valuation model, however, some market participants, particularly those trading only the simplest products, e.g., TBAs, use empirical hedge ratios or deltas. These can be computed from market data. Table 21-6 shows a major dealer's empirical hedge ratios as of December 2010 for various 30-year FNMA TBAs against 5 -and 10-year U.S. Treasuries. For example, to hedge a long position in 100 face amount of the 4.0% TBAs, the current coupon, requires the sale of 66 face amount of on-the-run 10-year Treasuries or 115 face amount of 5-year Treasuries.

As expected, the hedge ratios in Table 21-6 fall with coupon. Since higher coupons prepay faster, they are effectively shorter-term securities and, as such, have lower interest rate sensitivities. Of course, this table says nothing about the curve exposure of TBAs. It may be better to hedge with a combination of 5 -and 10-year Treasuries, or even with a 7-year Treasury, than to hedge with either a 5- or 10-year Treasury.

TABLE 21-6 Empirical Hedges of TBAs with U.S. Treasuries as of December 9, 2010

FNMA 30-Year TBA Coupon	Treasury Hedge Ratios	
	10-Year	5-Year
3%	0.93	1.64
3.5%	0.80	1.40
4%	0.66	1.15
4.5%	0.54	0.94
5%	0.43	0.75
5.5%	0.35	0.61
6%	0.28	0.50
6.5%	0.23	0.40

Source: JPMorgan Chase.

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Option Adjusted Spread

Option Adjusted Spread (OAS) is the most popular measure of relative value for MBS.[a] The method in a Monte Carlo framework is analogous to computing OAS in the context of interest rate trees: find the single spread such that shifting the paths of short-term rates by that spread results in a model value equal to the market price. To the extent that the model accounts correctly for scheduled cash flows and prepayments, the OAS represents the deviation of a security's market price from its fair value. Furthermore, when OAS is constant the return on a security hedged by a correct model is the short-term rate plus the OAS. Of course, to the extent that a model does not correctly account for prepayments, the OAS will be a blend of relative value and left-out factors.

The practical challenge of using models and OAS to measure relative value is in determining when OAS really does indicate relative value and when it indicates that the model is misspecified. A particular security is most likely mispriced when its OAS is significantly positive or negative while, at the same time, all substantially similar securities trade at an OAS near zero. In practice, however, this is rarely the case. Much more common is the situation in which a model finds relative value across a segment of the market, e.g., finding that premium or high-coupon mortgages are relatively cheap. Deciding whether that segment is really mispriced or whether the model is miscalibrated is the art of relative value trading.

One useful approach in determining whether the OAS of a sector indicates trading opportunities is to graph OAS over time and look for mean reversion. It may prove profitable to buy high-coupon mortgages at high OAS if the model finds that the sector used to trade at zero or negative OAS or, even better, if the sector's OAS oscillates with relatively high frequency around zero. But if the OAS of high-coupon mortgages has been fixed at a particular level over a long period of time, it is likely that it is a feature of the market rather than a mispricing to be exploited. Another useful approach is to determine whether there are any institutional or technical reasons to explain why a particular segment of the market would trade rich or cheap. The combination of an empirical finding of relative value combined with a supporting story can be quite convincing.

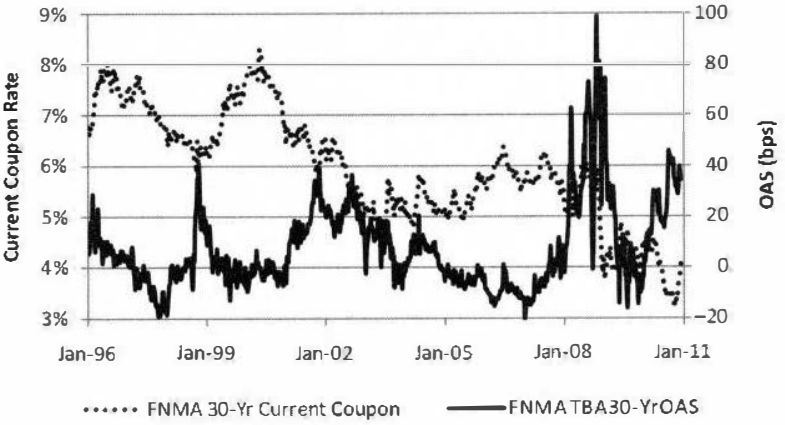

FIGURE 21-4 OAS of the FNMA TBA 30-year, as calculated by a major broker-dealer, with the FNMA 30-year current coupon.

Turning the discussion to hedging, it can be argued that OAS should be uncorrelated with interest rate movements: the valuation model is supposed to account completely for the effects of interest rates on cash flows and discounting. Furthermore, it is most convenient that OAS be uncorrelated with interest rates because, in that case, interest rate risk can be hedged with the exposures calculated by the model. On the other hand, if OAS is correlated with rates, then that correlation has to be hedged as well to construct a truly rate-neutral position. All in all, this line of reasoning suggests that relative value trading and hedging be restricted to models that produce OAS that are essentially uncorrelated with rates. The only counterargument would be that market mispricings or, alternatively, risk preferences, may, in fact, be correlated with the level of rates.

Figure 21-4 shows the OAS of the FNMA 30-year TBA, as computed by a major broker-dealer, along with the current coupon rate. The OAS of this benchmark mortgage

[a] Another sometimes-used measure is the *zero-volatility spread*. This is computed by assuming that forward rates are realized, computing prepayments, discounting using those forward rates, and finding the spread above forward rates that results in a model price equal to the market price. While easy to compute, this measure has serious theoretical drawbacks. First, forward rates are not expected rates, so valuation is not taking place along the expected path. Second, even if it were, price equals the expected discounted value not the discounted expected value.

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security displays relative value fluctuations from cheap to rich and back, i.e., the series appears to be mean reverting. The OAS also seems to be relatively uncorrelated with the level of mortgage rates. In short, the model does seem like a good candidate for relative value trading. Turn then to the 2007–2009 crisis. With credit concerns rife, the TBA OAS broke out of its band, peaking at an unprecedented 100 basis point of cheapness. *Ex ante*, should a trader have bought TBAs as the OAS of the TBA broke out of its band during the crisis, reaching 60 or 70 basis points? Could the trade be sustained through the OAS peak of 100 basis points so as to reap the profits of its eventually falling to zero? Or, *ex ante*, should the OAS have been considered a reasonably accurate reflection of deteriorating credit conditions and not an indicator of a relative value opportunity?

PRICE-RATE BEHAVIOR OF MBS

Figure 21-5 shows the rate behavior of a 5% 30-year MBS along with two other price curves for reference. The dotted curve is the price-rate curve of a (fictional) mortgage with scheduled interest and principal payments only, that is, with no prepayments. Not surprisingly, the curve looks like that of any security with fixed cash flows: it is decreasing in rates and positively convex. The dashed curve gives the price of mortgage with a constant CPR of 6%, which is the CPR of the *S*-curve in Figure 21-2 for sufficiently negative incentives. (The portion of this curve in the right half of the graph coincides with the solid curve, which will be discussed presently.) Since a fixed CPR leads to just another set of fixed cash flows, the price behavior of the dashed line is, like the dotted line, qualitatively similar to any security with fixed cash flows. A mortgage with a CPR of 6%, however, is effectively a shorter-term security than an otherwise identical mortgage with a CPR of 0%. Hence, the *DV*01 of the dashed curve is less than the *DV*01 of the dotted curve at any given level of rates.

The solid curve in Figure 21-5 is the price-rate curve of a 5% 30-year MBS with prepayments governed by the *S*-curve in Figure 21-2. For very high rates, i.e., negative incentives, the CPR of the MBS is 6% and the solid line corresponds to the dashed line discussed in the previous paragraph. As rates fall, and the value of the scheduled cash flows rise, CPR increases. This means that principal is repaid at par and that the value of the MBS cannot continue increasing as rates fall. This qualitative price-rate behavior is very much like that of callable bonds with an important difference. Since the exercise of callable bonds is close to efficient, a corporation that can call its bonds at par does so: the bond's value cannot, therefore, rise much above par. In the case of mortgages, however, borrowers do not prepay when they "ought" to, in a strict present value sense, enabling the value of a mortgage at low rates to rise above par, as it does in the figure. Finally, note that, because of the prepayment option, the price-rate curve of the mortgage is negatively convex at lower rates. This is very much analogous to the negative convexity of the price-rate curve of a callable bond.

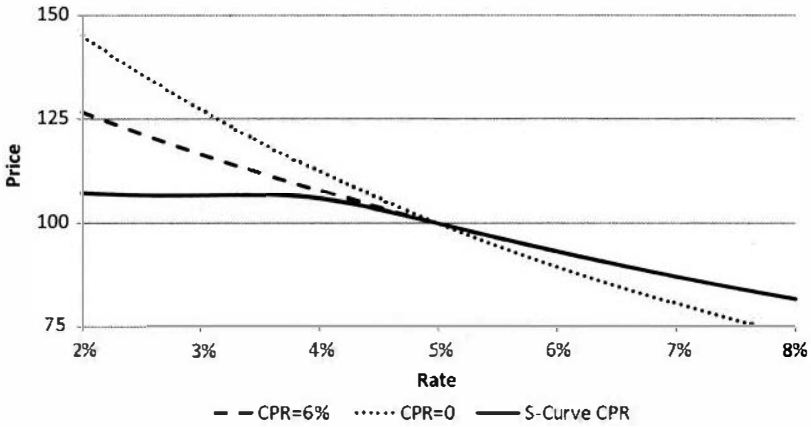

FIGURE 21-5 Price-rate curve of a 5% 30-year MBS with prepayments from the *S*-curve of Figure 21-2 along with two curves of 5% 30-year mortgages at fixed CPRs.

Figure 21-6 graphs the price of the same 5% 30-year MBS, labeled here as a pass-through, along with the prices of its associated IO and PO. When rates are very high and prepayments low, the PO is like a zero coupon bond, paying nothing until maturity. As rates fall and prepayments accelerate, the value of the PO rises dramatically. First, there is the usual effect that lower rates increase present values. Second, since the PO is like a zero coupon bond, it will be particularly sensitive to this effect. Third, as prepayments increase, some of the PO, which sells at a discount, is redeemed at par. Together,

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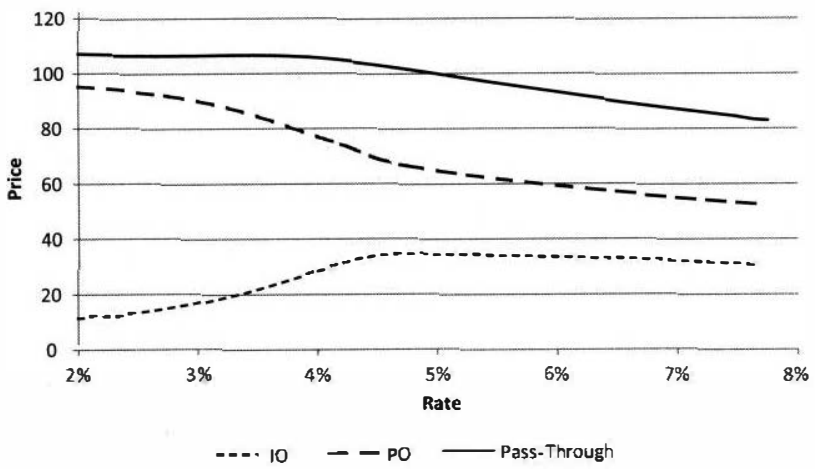

FIGURE 21-6 Price-rate curve of a 5% 30-year MBS with prepayments from the *S*-curve of Figure 21-2 along with the price-rate curves of its associated IO and PO.

these three effects make PO prices particularly sensitive to interest rate changes.

The price-rate curve of the IO is, of course, the pass-through curve minus the PO curve, but it is instructive to describe the IO curve independently. When rates are very high and prepayments low, the IO is like a security with a fixed set of cash flows. As rates fall and mortgages begin to prepay, the cash flows of an IO vanish. Interest lives off principal. Whenever some principal is paid off there is less available from which to collect interest. But, unlike callable bonds or pass-throughs that receive such prepaid principal, when prepayments cause interest payments to stop or slow the IO gets nothing. Once again, its cash flows simply vanish. This effect swamps the discounting effect so that, when rates fall, IO values decrease dramatically. The negative *DV*01 or duration of IOs, an unusual feature among fixed income products, may be valued by traders and portfolio managers in combination with more regularly behaved fixed income securities.

HEDGING REQUIREMENTS OF SELECTED MORTGAGE MARKET PARTICIPANTS

As mentioned earlier in the chapter, mortgage servicers are responsible for managing mortgage loans and passing cash flows from the borrowers to the lenders. Servicers are paid a fee for this service, typically between 20 and 50 basis points of the notional amount. If a loan is prepaid, the fee stream from that loan ends. Hence, while the valuation of *mortgage servicing rights (MSR)* is quite complex, some qualitative features of that business resemble the characteristics of IOs. From this perspective, mortgage servicers stand to lose revenue and value as rates fall. There is an offsetting effect, however: to the extent that borrowers refinance and servicers collect fees on the newly issued mortgages, and to the extent that lower rates actually increase the notional of mortgages outstanding, servicers might not lose very much from declining rates. But a servicer that has decided to hedge some of its revenue stream from falling rates faces a challenge. Hedging an IO-like security with a TBA would entail a severe convexity mismatch, conceptually similar to the discussion in the context of futures and options in the hedging application, but quantitatively much worse a problem. Hedging with swaps also entails a convexity mismatch and suffers, in addition, from mortgage-swap basis risk, i.e., the risk that mortgage rates and swap rates move by different amounts or, worse, in opposite directions. The risk profile of the securities mentioned in the subsection "Other Products" in this chapter might be better suited to this hedging problem, but their relative lack of liquidity limits their usefulness to hedgers of the size of servicers.

Lenders in the primary market, meaning financial institutions that lend money directly to mortgage borrowers, also have interest rate risk to hedge. From the time that the lender and borrower agree on the terms of a loan until the time the lender sells the loan to be securitized, the lender is exposed to the risk that rates will rise and result in the loan's losing value. Selling TBAs is a fine solution to this hedging problem. Secondary market originators that buy mortgages from lenders in the primary market and sell these mortgages through securitizations face the same risk as primary lenders. Rates may rise between the time the mortgages are bought and the time they are sold.

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APPENDIX

Major Exchanges Trading Futures and Options

Australian Securities Exchange (ASX)	www.asx.com.au
BM&FBOVESPA (BMF)	www.bmfbovespa.com.br
Bombay Stock Exchange (BSE)	www.bseindia.com
Boston Options Exchange (BOX)	www.bostonoptions.com
Bursa Malaysia (BM)	www.bursamalaysia.com
Chicago Board Options Exchange (CBOE)	www.cboe.com
China Financial Futures Exchange (CFFEX)	www.cffex.com.cn
CME Group	www.cmegroup.com
Dalian Commodity Exchange (DCE)	www.dce.com.cn
Eurex	www.eurexchange.com
Hong Kong Futures Exchange (HKFE)	www.hkex.com.hk
IntercontinentalExchange (ICE)	www.theice.com
International Securities Exchange (ISE)	www.iseoptions.com
Kansas City Board of Trade (KCBT)	www.kcbt.com
London Metal Exchange (LME)	www.lme.co.uk
MEFF Renta Fija and Variable, Spain	www.meff.es
Mexican Derivatives Exchange (MEXDER)	www.mexder.com
Minneapolis Grain Exchange (MGE)	www.mgex.com
Montreal Exchange (ME)	www.m-x.ca
NASDAQ OMX	www.nasdaqomx.com
National Stock Exchange, Mumbai (NSE)	www.nseindia.com
NYSE Euronext	www.nyse.com
Osaka Securities Exchange (OSE)	www.ose.or.jp
Shanghai Futures Exchange (SHFE)	www.shfe.com.cn
Singapore Exchange (SGX)	www.sgx.com
Tokyo Grain Exchange (TGE)	www.tge.or.jp
Tokyo Financial Exchange (TFX)	www.tfx.co.jp
Zhengzhou Commodity Exchange (ZCE)	www.zce.cn

There has been a great deal of consolidation of derivatives exchanges, nationally and internationally, in the last few years. The Chicago Board of Trade and the Chicago Mercantile Exchange have merged to form the CME Group, which also includes the New York Mercantile Exchange (NYMEX). Euronext and the NYSE have merged to form NYSE Euronext, which now owns the American Stock Exchange (AMEX), the Pacific Exchange (PXS), the London International Financial Futures Exchange (LIFFE), and two French exchanges. The Australian Stock Exchange and the Sydney Futures Exchange (SFE) have merged to form the Australian Securities Exchange (ASX). The IntercontinentalExchange (ICE) has acquired the New York Board of Trade (NYBOT), the International Petroleum Exchange (IPE), and the Winnipeg Commodity Exchange (WCE), and is merging with NYSE Euronext. Eurex, which is jointly operated by Deutsche Börse AG and SIX Swiss Exchange, has acquired the International Securities Exchange (ISE). No doubt the consolidation has been largely driven by economies of scale that lead to lower trading costs.

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