CHAPTER 16

Options Markets

Introduction: Short History of the Derivative Market

In the 1840s, Chicago emerged as a transportation and distribution center for agriculture products. Midwestern farmers transported and sold their products to wholesalers and merchants in Chicago, who often would store and later transport the products by either rail or the Great Lakes to population centers in the East. Partly because of the seasonal nature of grains and other agriculture products and partly because of the lack of adequate storage facilities, farmers and merchants began to use *forward contracts* as a way of circumventing storage costs and pricing risk. These contracts were agreements in which two parties agreed to exchange commodities for cash at a future date, but with the terms and the price agreed upon in the present. For example, an Iowa farmer in July might agree to sell his expected wheat harvest to a Chicago grain dealer in September at an agreed-upon price. This forward contract enabled both the farmer and the dealer to lock in the September wheat price in July. In 1848, the Chicago Board of Trade (CBT) was formed by a group of Chicago merchants to facilitate the trading of grain. This organization subsequently introduced the first standardized forward contract, called a "to-arrive" contract. Later, it established rules for trading the contracts and developed a system in which traders ensured their performance by depositing good-faith money to a third party. These actions made it possible for speculators as well as farmers and dealers who were hedging their positions to trade their forward contracts. By definition, *futures* are marketable forward contracts. Thus, the CBT evolved from a board offering forward contracts to the first organized exchange listing futures contracts—a futures exchange.

Futures Market

Since the 1840s, as new exchanges were formed in Chicago, New York, London, Singapore, and other large cities throughout the world, the types of futures contracts grew from grains and agricultural products to commodities and metals and finally to financial futures: futures on foreign currency, debt securities, and security indexes. Because of their use as a hedging tool by financial managers and investment bankers, the introduction of financial futures in the early 1970s led to a dramatic growth in futures trading, with the users' list reading as a who's who of major investment houses, banks, and corporations. The financial futures market formally began in 1972 when the Chicago Mercantile Exchange (CME) created the International Monetary Market (IMM) division, to trade futures contracts on foreign currency. In 1976, the CME extended its listings to include a futures contract on a Treasury bill. The CBT introduced its first futures contract in October 1975 with a contract on the Government National Mortgage Association (GNMA) pass-through, and in 1977 they introduced the Treasury bond futures contract. The Kansas City Board of Trade was the first exchange to offer trading on a futures contract on a stock index, when it introduced the Value Line Composite Index (VLCI) contract in 1983. This was followed by the introduction of the Standard & Poor's (S&P) 500 futures contract by the CME and the New York Stock Exchange (NYSE) index futures contract by the New York Futures Exchange (NYFE).

Whereas the 1970s marked the advent of financial futures, the 1980s saw the globalization of futures markets with the openings of the London International Financial Futures Exchange (LIFFE) in 1982, Singapore International Monetary Market in 1986, Toronto Futures Exchange in 1984, New Zealand Futures Exchange in 1985, and Tokyo Financial Futures Exchange in 1985. Exhibit 16.1 shows the Bloomberg CTM screen that lists the major exchanges trading futures and derivatives. The increase in the number of futures exchanges internationally led to a number of trading innovations: electronic trading systems, 24-hour worldwide trading, and alliances between exchanges. Concomitant with the growth in future trading on organized exchanges has been the growth in futures contracts offered and traded on the over-the-counter (OTC) market. In this market, dealers offer and make markets in more tailor-made forward contracts in currencies, indexes, and various interest rate products. Today, the total volume of forward contracts created on the OTC market exceeds the volume of exchange-traded futures contracts. The combined growth in the futures and forward contracts has also created a need for more governmental oversight to ensure market efficiency and to guard against abuses. In 1974 the Commodity Futures Trading Commission (CFTC) was created by Congress to monitor and regulate futures trading, and in 1982 the National Futures Association (NFA), an organization of futures market participants, was established to oversee futures trading. Finally, the growth in futures markets led to the consolidation of exchanges. In 2006, the CME and the CBT approved a deal in which the CME acquired the CBT, forming the CME Group, Inc.


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Contract Table Menu
Show
Categories
Exchange
Region
Agriculture and Livestock
1) CORN - Corn
2) FIBR - Fibers
3) FOOD - Foodstuff
4) LSTK - Livestock
5) OGRN - Other Grain
6) SOY - Soy
7) WHET - Wheat
Energy and Environment
8) COAL - Coal
9) CRDO - Crude Oil
10) ETCY - Electricity
11) EMIS - Emissions
12) NATG - Natural Gas
13) REFP - Refined Products
14) SHIP - Shipping
15) WTHR - Weather
Financial Contracts
16) BOND - Bond
17) CDS - Credit Derivatives
18) XCUR - Cross Currency
19) CURR - Currency
20) INTR - Interest Rate
21) CURO - Spot Currency Options
22) SWAP - Swap
23) SYNS - Synthetic Interest Rate Strip
24) WBON - Weekly Bond Options
25) WCUR - Weekly Currency Options
Index Contracts
26) EQIX - Equity Index
27) EIXO - Equity Index Spot Options
28) VIXO - Equity Volatility Index Option
29) NEIX - Non-Equity Index
30) NEXO - Non-Equity Index Spot Options
31) WIXO - Weekly Index Options
Metals and Industrials
32) BMTL - Base Metal
33) IMAT - Industrial Material
34) PMTL - Precious Metal

(a)


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Contract Exchange Menu
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Categories
Exchange
Region
North America
1) AMX - American Stock Exchange
2) C02 - C2 Options Exchange
3) CBF - CBOE Futures Exchange
4) CBT - Chicago Board of Trade
5) CBO - Chicago Board Options Exchange
6) CME - Chicago Mercantile Exchange
7) CMX - COMEX division of NYMEX
8) ELX - ELX Futures
9) ERI - Eris Exchange
10) GFV - Green Exchange Venture
11) WCE - ICE Futures Canada
12) FNX - ICE Futures US Currencies
13) NYF - ICE Futures US Indices
14) NYB - ICE Futures US Softs
15) ISE - International Securities Exchange
16) KCB - Kansas City Board of Trade
17) MDX - Mercado Mexicano de Derivados
18) MGE - Minneapolis Grain Exchange
19) MCE - Montreal Climate Exchange
20) MSE - Montreal Exchange
21) NFX - NASDAQ OMX Futures Exchange
22) PHL - NASDAQ OMX PHLX
23) NCP - NYMEX Clearport
24) NDM - NYMEX DME
25) NYM - NYMEX Exchange
26) NYL - NYSE LIFFE U.S.
27) OCG - OneChicago
28) OTC - Over The Counter
South America
29) BMF - Bolsa De Mercadorias & Futuros
30) BOV - Bolsa de Valores de Sao Paulo
31) CDE - Colombia Derivatives Exchange
32) DVX - Colombia Derivex
33) SBA - Merc. de Valores Buenos Aires
34) MBA - Mercado a Termino Buenos Aires
35) MAE - Mercado Abierto Electronico
36) RFX - Rosario Futures Exchange
Europe
37) ADE - Athens Derivative Exchange
38) BNF - Bluenext
39) MIL - Borsa Italiana (IDEM)

(b)

(c)

(d)

EXHIBIT 16.1 Major Futures and Derivative Exchanges

Formally, a forward contract is simply an agreement between two parties to trade a specific asset at a future date with the terms and price agreed upon today. A futures contract, in turn, is a "marketable" forward contract, with marketability (the ease or speed in trading a security) provided through futures exchanges that not only list hundreds of contracts that can be traded but provide the mechanisms for facilitating trades. Futures and forward contracts are known as *derivative securities*. A derivative security is one whose value depends on the values of another asset (e.g., the price of the underlying commodity or security). Another important derivative is an option. An option is a security that gives the holder the right, but not the obligation, to buy or sell a particular asset at a specified price on, or possibly before, a specific date.

Options Markets

Like the futures market, the option market in the United States can be traced back to the 1840s when options on corn meal, flour, and other agriculture commodities were traded in New York. These option contracts gave the holders the right, but not the obligation, to purchase or to sell a commodity at a specific price on or possibly before a specified date. Like forward contracts, options made it possible for farmers or agriculture dealers to lock in future prices. In contrast to commodity futures trading, however, the early market for commodity option trading was relatively thin. The market did grow marginally when options on stocks began trading on the over-the-counter (OTC) market in the early 1900s. This market began when a group of investment firms formed the Put and Call Brokers and Dealers Association. Through this association, an investor who wanted to buy an option could do so through a member who either would find a seller through other members or would sell (write) the option himself.

The OTC option market was functional, but suffered because it failed to provide an adequate secondary market. In 1973, the Chicago Board of Trade (CBT) formed the Chicago Board Options Exchange (CBOE). The CBOE was the first organized option exchange for the trading of options. Just as the CBT had served to increase the popularity of futures, the CBOE helped to increase the trading of options by making the contracts more marketable. Since the creation of the CBOE, organized stock exchanges in the United

States, most of the organized futures exchanges, and many security exchanges outside the United States also began offering markets for the trading of options. As the number of exchanges offering options increased, so did the number of securities and instruments with options written on them. Today, option contracts exist not only on stocks but also on foreign currencies, indexes, futures contracts, and debt and interest rate-sensitive securities.

In addition to options listed on organized exchanges, there is also a large OTC market in currency, debt, and interest-sensitive securities and products in the United States and a growing OTC market outside the U.S. OTC debt derivatives are primarily used by financial institutions and nonfinancial corporations to manage their interest rate positions. The derivative contracts offered in the OTC market include spot options and forward contracts on Treasury securities, London Interbank Offered Rate–related (LIBOR-related) securities, and special types of interest rate products, such as interest rate calls and puts, caps, floors, and collars. OTC interest rate derivatives products are typically private, customized contracts between two financial institutions or between a financial institution and one of its clients.

Overview

Futures and options contracts on stock, debt, and currency, as well as such hybrid derivatives as swaps, interest rate options, caps, and floors, are an important risk-management tool. Farmers, portfolio managers, multinational businesses, and financial institutions often buy and sell derivatives to hedge positions they have in the derivative's underlying asset against adverse price changes. Derivatives also are used for speculation. Many investors find buying or selling options or taking futures positions an attractive alternative to buying or selling the derivative's underlying security. Finally, many institutional investors, portfolio managers, and corporations use derivatives for *financial engineering*, combining their debt, equity, or currency positions with different derivatives to create a structured investment or debt position with certain desired risk-return features.

In this chapter, we examine the option market, describing the markets in which equity derivatives are traded, how they are used for speculating and hedging, and how their prices are determined. In Chapter 17, we examine futures markets and how futures contracts are used for speculating, hedging, and financial engineering.

Option Strategies

Option Terminology

By definition, an option is a security that gives the holder the right to buy or sell a particular asset at a specified price on, or possibly before, a specific date. A call option would be created, for example, if on March 1, Ms. A paid $1,000 to Mr. B for a contract that gives Ms. A the right, but not the obligation, to buy "ABC Properties" from Mr. B for $100,000 on or before July 1. Similarly, a put option also would be created if Mr. B sold Ms. A a contract for the right, but not the obligation, to sell "ABC Properties" to Mr. B for $100,000 on or before July 1.

Depending on the parties and types of assets involved, options can take on many different forms. Certain features, however, are common to all options. First, with every option contract there is a right, but not the obligation, to either buy or sell. Specifically, by definition, a *call* is the right to buy a specific asset or security, whereas a *put* is the right to sell. Second, every option contract has a buyer and seller. The option buyer is referred to as the *holder* and as having a *long* position in the option. The holder buys the right to *exercise* or evoke the terms of the option claim. The seller, often referred to as the option *writer*, has a *short* position and is responsible for fulfilling the obligations of the option if the holder exercises it. Third, every option has an option price, exercise price, and exercise date. The price paid by the buyer to the writer for the option is referred to as the *option premium* (call premium and put premium). The *exercise price* or *strike price* is the price specified in the option contract at which the underlying asset can be purchased (call) or sold (put). Finally, the *exercise date* is the last day the holder can exercise. Associated with the exercise date are the definitions of European and American options. A *European option* is one that can be exercised only on the exercise date, and an *American option* can be exercised at any time on or before the exercise date. Thus, from our previous example, Mr. B is the writer, Ms. A is the holder, $1,000 is the option premium, $20,000 is the exercise or strike price, July 1 is the exercise date, and the option is American.

Exhibit 16.2 shows price quotes on a number of call and put options on Procter and Gamble stock as of 5/15/2013 from the Bloomberg OMON screen. Each option contract is characterized by its strike or exercise price, expiration, and whether it is a call or put. As shown on the call screen, on 5/15/2013, P&G stock closed at 80.68, the last price on the P&G call option with an exercise price of 80 and expiration of June 13, 2013, was 1.82, and dealers were offering to sell the option (Ask) at 1.81 and to buy (Bid) the option at 1.78. Note that the contract size on the option is 100, meaning that the contract calls for buying or selling 100 options. Most stock option contracts call for 100 options. Later in this chapter, we will examine options listed on exchanges in more detail.

EXHIBIT 16.2 Bloomberg OMON, Screen: Call Options on P&G

Fundamental Option Strategies

Many types of option strategies with names such as straddles, strips, spreads, combinations, and so forth, exist. The building blocks for these strategies are six fundamental option strategies: call and put purchases, call and put writes, and call and put writes in which the seller covers her position. The features of these strategies can be seen by examining the relationship between the price of the underlying security and the possible profits or losses that would result if the option either is exercised or expires worthless.[1]

Call Purchase

To see the major characteristics of a call purchase, suppose an investor buys a call option on P&G stock with an exercise price (X) of $80 at a call premium ($C$) of $3. If the stock price reaches $90 and the holder exercises the option, a profit of $7 will be realized as the holder acquires the P&G stock for $80 by exercising and then sells it in the market for $90: A $10 capital gain minus the $3 premium. If the holder exercises when the stock is trading at $83, he will break even: The $3 premium will be offset exactly by the $3 gain realized by acquiring the stock from the option at $80 and selling in the market at $83. Finally, if the price of the P&G is at $80 or below, the holder will not find it profitable to exercise, and as a result, he will let the option expire, realizing a loss equal to the call premium of $3. Thus, the maximum loss from the call purchase is $3.

The investor's possible profit/loss and stock price combinations can be seen graphically in Exhibit 16.3 and in the accompanying Bloomberg table. In the graph, the profits/losses are shown on the vertical axis and the market prices of the stock at the time of the exercise and/or expiration (signified as T: S_T) are shown along the horizontal axis. This graph is known as a *profit graph* and was generated from the Bloomberg OSA screen for a P&G option with an exercise price of 80 and expiration of October 19, 2013. The line from the coordinate (80, −3) to the (90, 7) coordinate and beyond shows all the profits and losses per call associated with each stock price. That is, the (90, 7) coordinate shows the $7 call profit realized when P&G is at $90, and the (85, 2) coordinate shows a profit of $2 when the stock is at $85. The horizontal segment shows a loss of $3, equal to the premium paid when the option was purchased. Finally, the horizontal intercept shows the break-even price at $83. The break-even price can be found algebraically by solving for the stock price at the exercise date (S_T) in which the profit (π) from the position is zero. The profit from the call purchase position is:

$$\pi = (S_T - X) - C_0$$

where:

C_0 is the initial (t = 0) cost of the call.

Setting π equal to zero and solving for S_T yields the break-even price of S^*_T:

$$S_T^* = X + C_0 = \$80 + \$3 = \$83$$

(a)

(b)

EXHIBIT 16.3 Call Purchase

The profit graph in Exhibit 16.3 highlights two important features of call purchases. First, the position provides an investor with unlimited profit potential; second, losses are limited to an amount equal to the call premium. These two features help explain why some speculators prefer buying a call rather than the underlying stock itself. In this example, suppose that the price of P&G could range from $60 to $100 at expiration. If a speculator purchased the stock for $80, the profit from the stock would range from −$20 to +$20, or in percentage terms, from −25 percent to +25 percent. On the other hand, the return on the call option would range from +467 percent (= [($100 – $80 – $3)/$3] - 1) to −100 percent (= [−$3/$3] - 1)! Thus, the potential reward to the speculator from buying a call instead of the stock can be substantial —in this example, 467 percent compared to 25 percent for the stock, but the potential for loss also is large, −100 percent for the call versus −25 percent for the stock.

In addition to the profit graph, option positions also can be described graphically by value graphs. A value graph shows the option's value or cash flow at expiration, associated with each level of the stock price. The graph shows that if $S_T \leq X$ ($S_T \leq \$80$), then the call will have no value ($C_T = 0$), whereas if $S_T > X$ ($S_T > \$80$), then the call will have a value of $C_T = S_T - X$.

Naked Call Write

The second fundamental strategy involves the sale of a call in which the seller does not own the underlying stock. Such a position is known as a *naked call write*. To see the characteristics of this position, consider the P&G call option with the exercise price of $80 and the call premium of $3. The profits or losses associated with each stock price from selling the call are depicted in Exhibit 16.4. As shown, when the price of the stock is at $90, the seller suffers a $7 loss if the holder exercises the right to buy the stock from the writer at $80. Since the writer does not own the stock, she would have to buy it in the market at its market price of $90, and then turn it over to the holder at $80. Thus, the call writer would realize a $10 capital loss, minus the $3 premium received for selling the call, for a net loss of $7. When the stock is at $83, the writer will realize a $3 loss if the holder exercises. This loss will offset the $3 premium received. Thus, the break-even price for the writer is $83, the same as the holder's. This price also can be found algebraically by solving for the stock price in which the profit from the naked call write position is zero:

$$\pi = (X - S_T) + C_0$$
$$0 = (X - S_T) + C_0$$
$$S_T^* = X + C_0$$
$$S_T^* = \$80 + \$3 = \$83$$

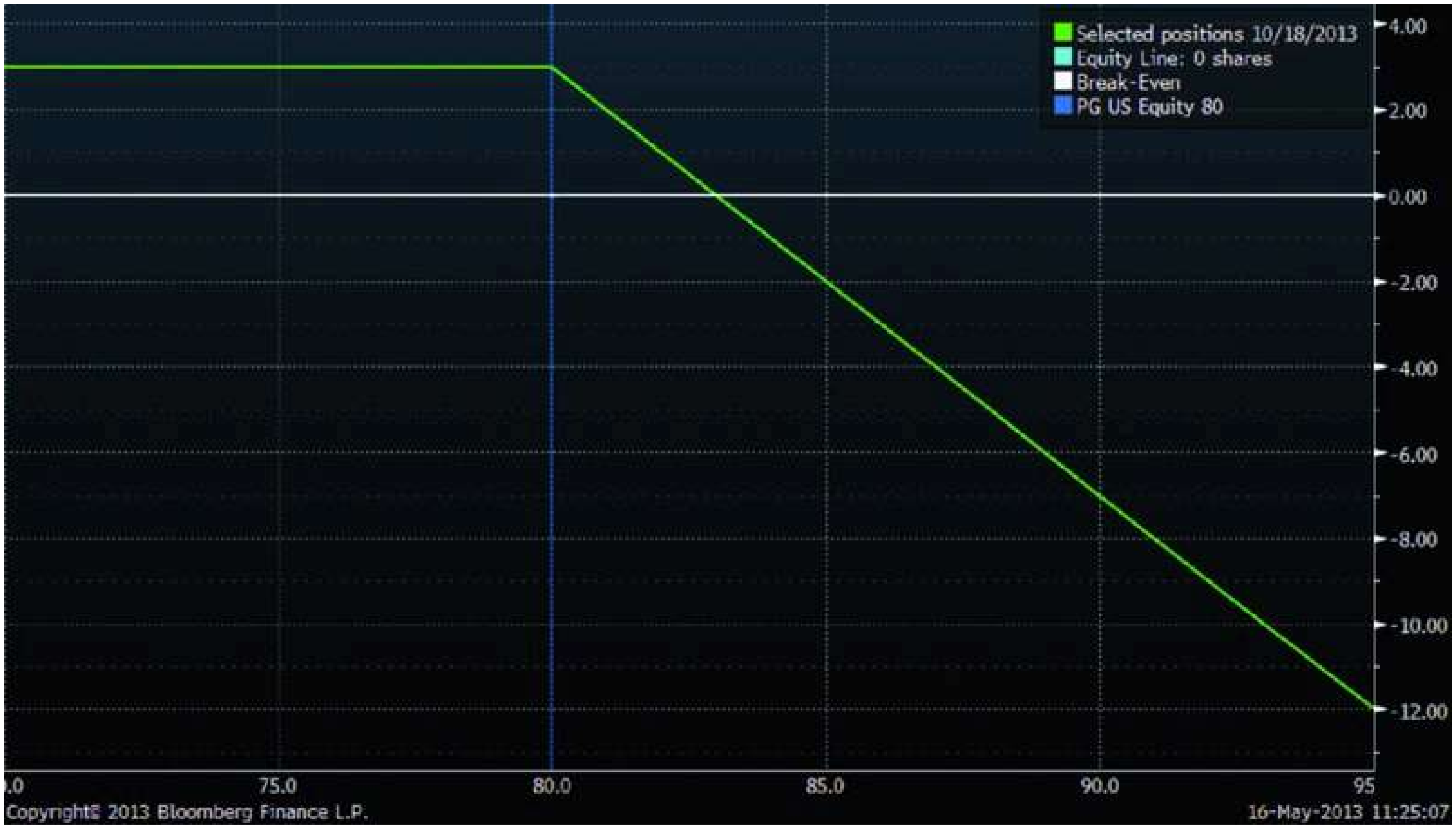


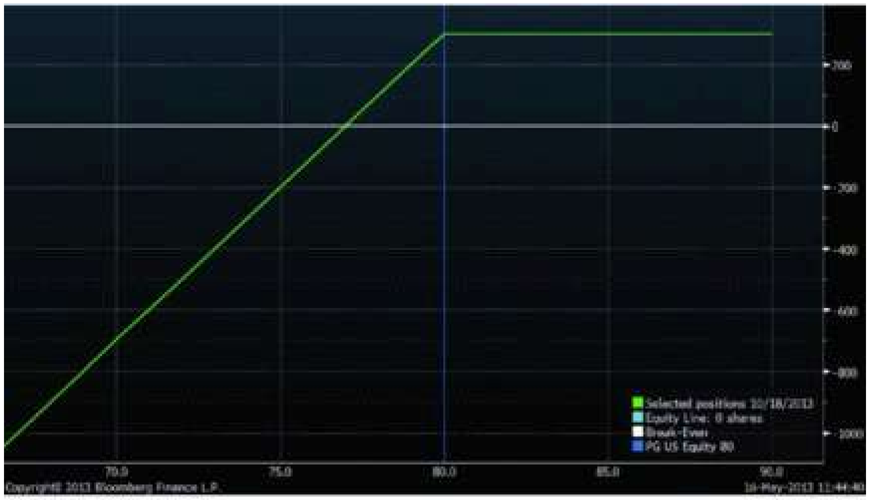
EXHIBIT 16.4 Naked Call Write

Finally, at a stock price of $80 or less the holder will not exercise, and the writer will profit by the amount of the premium, $3.

As highlighted in the graph, the payoffs to a call write are just the opposite of the call purchase; that is, gains/losses for the buyer of a call are exactly equal to the losses/gains of the seller. Thus, in contrast to the call purchase, the naked call write position provides the investor with only a limited profit opportunity equal to the value of the premium, with unlimited loss possibilities. Although this limited profit and unlimited loss feature of a naked call write may seem unattractive, the motivation for an investor to write a call is the cash or credit received and the expectation that the option will not be exercised. As we will discuss later, however, there are margin requirements on an option write position in which the writer is required to deposit cash or risk-free securities to secure the position.

Covered Call Write

One of the most popular option strategies is to write a call on a stock already owned. This strategy is known as a *covered call write*. For example, an investor who bought 100 shares of P&G stock at $80 some time ago and who did not expect its price to appreciate in the near future, might sell 100 calls on P&G (one call contract) with an exercise price of $80. As shown in Exhibit 16.5 and its accompanying Bloomberg table, if P&G is $80 or more, then the covered call writer loses the stock when the holder exercises, leaving the writer with a profit of only $3. The benefit of the covered call write occurs when the stock price declines. For example, if ABC stock declined to $70, then the writer would suffer an actual (if the stock is sold) or paper loss of $10. The $3 premium received from selling the call, however, would reduce this loss to just $7. Similarly, if the stock is at $77, a $3 loss will be offset by the $3 premium received from the call sale.



(a)

(b)

EXHIBIT 16.5 Cover Call Write

EXHIBIT 16.6 Put Purchase

Put Purchase

Since a put gives the holder the right to sell the stock, profit is realized when the stock price declines. With a decline, the put holder can buy the stock at a low price in the stock market, and then sell it at the higher exercise price on the put contract. To see the features related to a long put position, consider the P&G put option with an exercise price $80 priced at $3 ($P_0$). If the stock price declines to $70, the put holder could purchase P&G at $70 and then use the put contract to sell the stock at the exercise price of $80. Thus, as shown by the profit graph in Exhibit 16.6, at $70 the put holder would realize a $7 profit (the $10 gain from buying the stock and exercising minus the $3 premium). The break-even price in this case would be $77:

$$\pi = (X - S_T) - P_0$$
$$0 = (X - S_T) - P_0$$
$$S_T^* = X - P_0$$
$$S_T^* = \$80 - \$3 = \$77$$

Finally, if the stock is $80 or higher at expiration, it will not be rational for the put holder to exercise. As a result, a maximum loss equal to the $3 premium will occur when the stock is trading at $80 or more. The put purchase position can also be described by its value: if $S_T < X$, then the value of the put is $P_T = X - S_T$, and if $S_T \geq X$, then the put is worthless: $P_T = 0$.

Thus, similar to a call purchase, a long put position provides the buyer with potentially large profit opportunities (not unlimited since the price of the stock cannot be less than zero), while limiting the losses to the amount of the premium. Unlike the call purchase strategy, the put purchase position requires the stock price to decline before profit is realized.

Naked Put Write

The exact opposite position to a put purchase (in terms of profit/loss and stock price relations) is the sale of a put, defined as the *naked put write*. This position's profit graph for the P&G 80 put is shown in Exhibit 16.7. Here, if P&G is at $80 or more, the holder will not exercise and the writer will profit by the amount of the premium, $3. In contrast, if P&G decreases, a loss is incurred. For example, if the holder exercises at $70, the put writer must buy the stock at $80. An actual $10 loss will occur if the writer elects to sell the stock and a paper loss if he holds on to it. This loss, minus the $3 premium, yields a loss of \$7 when the market price is \$70. As indicated in the graph, the break-even price in which the profit from the position is zero is S^*_T = \$77, the same as the put holder's price:

$$\pi = (S_T - X) + P_0$$
$$0 = (S_T - X) + P_0$$
$$S_T^* = X - P_0$$
$$S_T^* = \$80 - \$3 = \$77$$

EXHIBIT 16.7 Naked Put Write

Covered Put Write

The last fundamental option strategy is the covered put write. This strategy requires the seller of a put to cover her position. Because a put writer is required to buy the stock at the exercise price if the holder exercises, the only way she can cover the obligation is by selling the underlying stock short. For example, suppose a writer of 100 P&G 80 puts shorts 100 shares of stock: borrows 100 shares of P&G stock and then sells it in the market at $80/share or $8,000. At expiration, if the stock price is less than the exercise price and the put holder exercises, the covered put writer will buy the 100 shares with the $8,000 proceeds obtained from the short sale and then return the shares that were borrowed to cover the short sale obligation. The put writer's obligation is thus covered, and she profits by an amount equal to the premium as shown in Exhibit 16.8. In contrast, losses from covered put write position occur when the stock price rises above $83. When the stock price is $80 or greater, the put is worthless and the holder would not exercise, but losses would occur from covering the short sale. For example, if the writer had to cover the short sale when P&G was trading at $90, she would incur a $1,000 loss (or $1,000 paper loss if she did not have to cover). This loss, minus the $300 premium the writer received, would equate to a net loss of $700. Finally, the break-even price for the covered put write in which profit is zero occurs at $83.

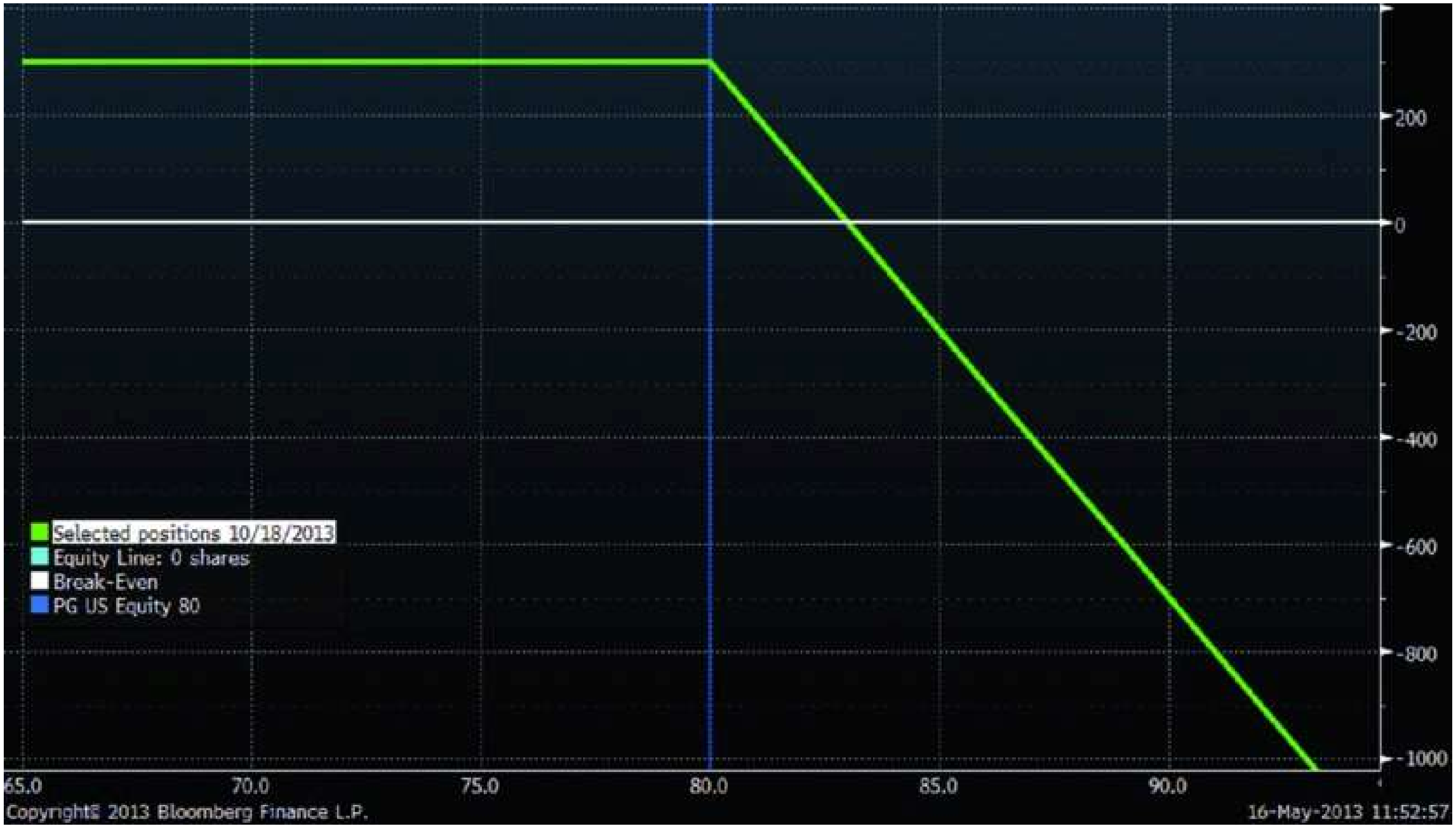


EXHIBIT 16.8 Covered Put Write

Other Option Strategies

One of the important features of an option is that it can be combined with the underlying security and other options to generate a number of different investment strategies. Two well-known strategies are the *straddle* and *spread*.

Straddle

A straddle purchase is formed by buying both a call and put with the same terms—same underlying stock, exercise price, and expiration date. A straddle write, in contrast, is constructed by selling a call and a put with the same terms.

In Exhibit 16.9, the profit graphs are shown for a straddle purchase for 100 P&G calls and 100 puts with exercise prices of $80 and premiums of $3.[2] The straddle purchase shown in the figure can be geometrically generated by vertically summing the profits on the call purchase position and put purchase position at each stock price. The resulting straddle purchase position is characterized by a V-shaped profit and stock price relation. Thus, the motivation for buying a straddle comes from the expectation of a large stock price movement in either direction. For example, at the stock price of $90, a $400 profit is earned: $1,000 profit on the 100 calls minus the $600 cost of the straddle purchase. Similarly, at $70, a $400 profit is attained: $1,000 profit on the 100 puts minus the $600 cost of the straddle. Losses on the straddle occur if the price of the underlying stock remains stable, with the maximum loss being equal to the costs of the straddle ($600) and occurring when the stock price is equal to the exercise price. Finally, the straddle is characterized by two break-even prices ($84 and $76).

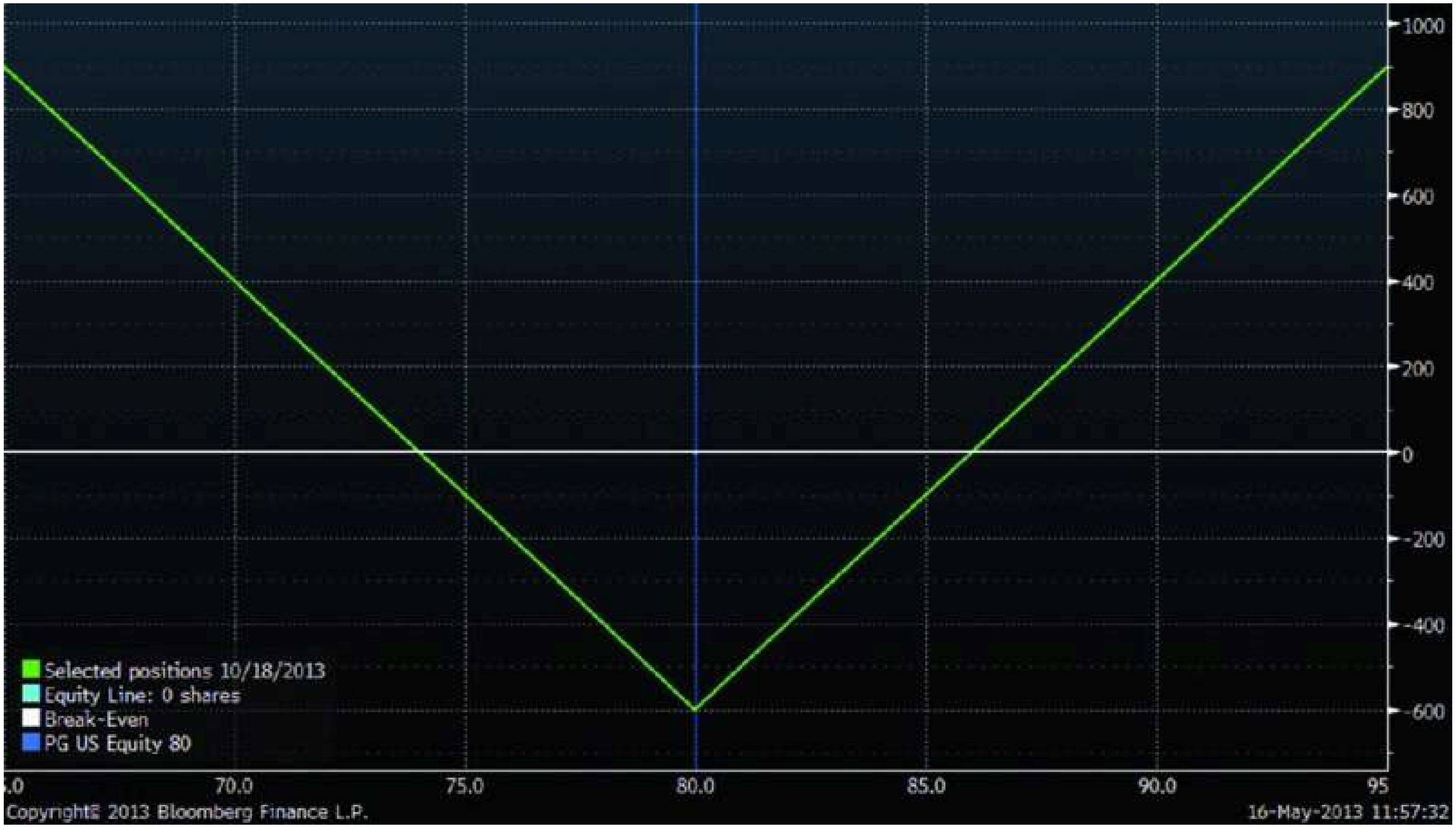


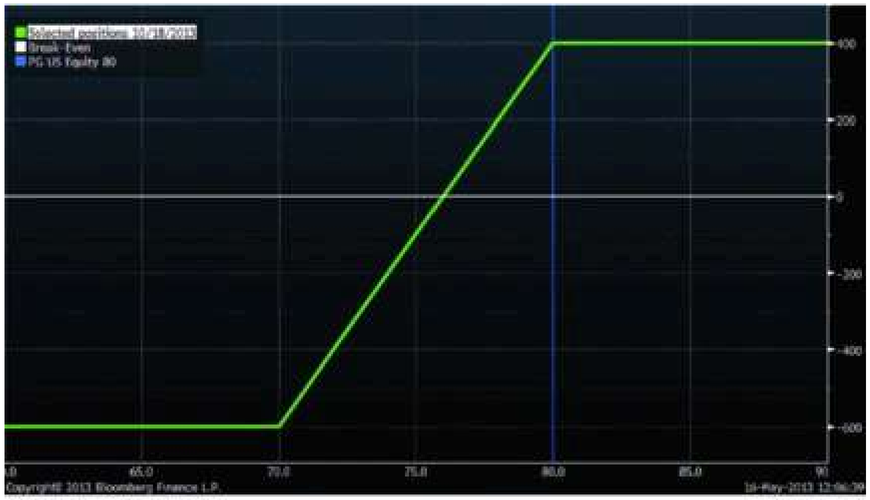
EXHIBIT 16.9 Straddle Purchase

In contrast to the straddle purchase, a straddle write yields an inverted V-shaped profit graph. The seller of a straddle is betting against large price movements. A maximum profit equal to the sum of the call and put premiums occurs when the stock price is equal to the exercise price; losses occur if the stock price moves significantly in either direction. A straddle write problem is included as one of the chapter problems found on the text web site.

Spread

A spread is the purchase of one option and the sale of another on the same underlying stock but with different terms: different exercise prices, different expirations, or both. Two of the most popular spread positions are the *bull spread* and the *bear spread*. A bull call spread is formed by buying a call with a certain exercise price and selling another call with a higher exercise price, but with the same expiration date. A bear call spread is the reversal of the bull spread; it consists of buying a call with a certain exercise price and selling another with a lower exercise price. (The same spreads also can be formed with puts.)

Exhibit 16.10 shows the profit graph and Bloomberg OSA table for a bull spread formed with the purchase of 100 P&G 70 calls (one contract), for $9 per call and the sale of 100 80 calls for $3 (same expirations). Geometrically, the profit and stock price relation for the spread shown in the figure can be obtained by vertically summing the profits from the long 70 call position and the short 80 call position at each stock price. The bull spread is characterized by losses limited to $400 when the stock price is $70 or less, limited profits of $600 starting when the stock price hits $80, and a break-even price of $76.



(a)

(b)

EXHIBIT 16.10 Bull Spread Purchase

A bear call spread results in the opposite profit and stock price relation as the bull spread: a limited profit occurs when the stock price is equal to or less than the lower exercise price and a limited loss occurs when the stock price is equal to or greater than the higher exercise price. A bear spread problem also is included as one of the chapter problems found on the text web site.

Other Positions

Between outright call and put positions, options can be combined in many different ways to obtain various types of profit relations. Speculators who expect prices on stocks to decrease in the future but don't want to assume the risk inherent in a put purchase position could form a bear call spread. In contrast, speculators who expect rates to be stable over the near term could, in turn, try to profit by forming a straddle write. Thus by combining different option positions, speculators can obtain positions that match their expectations and their desired risk-return preference. Given this, it should not be too surprising to find that options can be used to form synthetic securities such as long and short stock positions. A *simulated long position* can be formed by buying a call and selling a put with the same terms; it is equivalent to the profit and stock price relation associated with buying the underlying stock. Similarly, a *simulated short position* is constructed by selling a call and buying a put with the same terms; it is equivalent to the profit and stock price relation associated with selling the underlying stock short. Exhibit 16.11 lists some of the other option positions. Several exercises for generating profit tables and graphs for different option positions are included as part of the chapter problems found on the text web site.

1. **Bull Call Spread**: Long in call with low X and short in call with high X.
2. **Bull Put Spread**: Long in put with low X and short in put with high X.
3. **Bear Call Spread**: Long in call with high X and short in call with low X.
4. **Bear Put Spread**: Long in put with high X and short in put with low X.
5. **Long Butterfly Spread**: Long in call with low X, short in 2 calls with middle X, and long in call with high X (similar position can be formed with puts).
6. **Short Butterfly Spread**: Short in call with low X, long in 2 calls with middle X, and short in call with high X (similar position can be formed with puts).
7. **Straddle Purchase**: Long call and put with similar terms.
8. **Strip Purchase**: Straddle with additional puts (e.g., long call and long 2 puts).
9. **Strap Purchase**: Straddle with additional calls (e.g., long 2 calls and long put).
10. **Straddle Sale**: Short call and put with similar terms (strip and strap sales have additional calls and puts).
11. **Money Combination Purchase**: Long call and put with different exercise prices.
12. **Money Combination Sale**: Short call and put with different exercise prices.

EXHIBIT 16.11 Different Option Positions

OSA: BLOOMBERG'S OPTION SCENARIO SCREEN

Profit and value graphs for options can be generated using the Bloomberg OSA screen. To access OSA for a security, load the menu page of the security and type OSA (or click "OSA" from the menu). For example, for Procter and Gamble options do the following:

1. Go to stock or index equity menu screen: Ticker <Equity> <Return>.
2. Type "OSA."
3. On the OSA screen, click the "Positions" tab and then click "Add Listed Options" tab to bring up options listed on the stock. This brings up a screen showing the listed options from which to select, for example, 1 call contract (100 calls) and 1 put contract (100 puts).
4. After selecting the positions, type 1 <Enter> (or click) to load positions and bring up the OSA position screen.
5. On the position screen, click the "Scenario Chart" tab at the top of the screen to bring up the profit graph. The profit graph shows profits for the strategy at expiration where the option price is trading at its intrinsic value and also at time periods prior where the option price is determined by an option-pricing model. The profit graphs for different periods can be changed or deleted by clicking the select options box at the top of the screen.
6. From the position screen (click "Position" tab), you can select different positions and then click "Scenario Chart" tab to view the profit graph.
7. The scenario screen (gray "Scenario Chart" tab) shows the profit table; click "Maximize Chart" tab to see just the graph.
8. See Exhibits 16.3–16.10 for examples of tables and graphs generated from the OSA screen for P&G.

See Bloomberg Web Exhibit 16.1.

Option Price Relations

The market price of an option is a function of the time to expiration, the strike price, the price and the volatility of the underlying security, and the rate of return on a risk-free bond.

Call Price Relations

The relationship between the price of a call and its expiration time, exercise price, and stock price can be seen by defining the call's intrinsic value and time value premium. By definition, the *intrinsic value* (*IV*) of a call at a time prior to expiration (let *t* signify any time prior to expiration), or at expiration (*T* again signifies expiration date) is the maximum (Max) of the difference between the price of the stock (S_t) and the exercise price or zero (since the option cannot have a negative value):

$$IV = \text{Max}[S_t - X,\ 0]$$

Thus, if a call had an exercise price of $80 and the stock was trading at $90, then the intrinsic value of the call would be $10; if it were trading at $80 or less, the IV would be zero.

The intrinsic value can be used to define *in-the-money*, *on-the-money*, and *out-of-the-money* calls. Specifically, an in-the-money call is one in which the price of the underlying stock exceeds the exercise price; as a result, its *IV* is positive. When the price of the stock is equal to the exercise price, the call's *IV* is zero and the call is said to be on the money (or at the money). Finally, if the exercise price exceeds the stock price, the call would be out of the money and the *IV* would be zero:

Type	Condition	Example
In-the-Money:	$S_t > X \Rightarrow IV > 0$	$90 > 80 => *IV* = $10
On-the-Money:	$S_t = X \Rightarrow IV = 0$	$80 = $80 => *IV* = 0
Out-of-the-Money:	$S_t < X \Rightarrow IV = 0$	$70 < $80 => *IV* = 0

For an American call option, the *IV* defines a boundary condition in which the price of a call has to trade at value at least equal to its *IV*:

$$C_t \geq \text{Max}[S_t - X, 0]$$

If this condition does not hold ($C_t < \text{Max}[S_t - X, 0]$), then an arbitrageur could earn a riskless return by buying the call, exercising, and then selling the stock. For example, suppose an American call option on P&G stock with an exercise price of $80 was trading at $9 when the stock was trading at $90 (*IV* = Max($90 – $80, 0) = $10). In this situation we have an asset (the stock) selling at two different prices: one is $90, offered in the stock market; the other is $89 ($9 call premium plus $80 exercise price), available in the option market. In this case, an arbitrageur could realize a riskless profit of $1 (excluding commissions) per call by (1) buying the call at $9, (2) immediately exercising it (buying P&G stock at $80), and (3) selling the stock in the market for $90:

$S_t = 90$, $X = 80$, $C_t = 9$

Position	Cash Flow
Buy P&G 80 Call for 9	−9
Exercise P&G 80 Call: (Buy Stock for X = 80)	−80
Sell Stock in Market for 90	+90
Profit	+1

Arbitrageurs seeking to profit from this opportunity would increase the demand for the P&G call, causing its price to go up until the call premium was at least $10 and the arbitrage opportunity disappeared. Thus, in equilibrium, the American call would have to trade at a price at least equal to its *IV*.

It is important to note that the exploitation of arbitrage opportunities by arbitrageurs ensures that the price of the option will change as the underlying stock price changes. For example, if P&G stock were to increase from $90 to $95 to $100, then in the absence of arbitrage, the price of the 80 call would have to increase to a price that is at least equal to $15 when the stock is at $95 and $20 when the stock is at $100. Thus, arbitrageurs ensure that the call option derives its value from the underlying stock. Finally, note that since the above arbitrage strategy governing the price of an American option requires an immediate exercise of the call, the resulting *IV* boundary condition does not hold for European options.[3]

The other component of the value of an option is the *time value premium* (*TVP*). By definition, the *TVP* of a call is the difference between the price of the call and the *IV*:

$$TVP = C_t - IV$$

If the call premium were $12 when the price of the underlying stock on the 80 call was $90, the *TVP* would be $2. The *TVP* decreases as the time remaining to expiration decreases. Specifically, if the call is near expiration, we should expect the call to trade at close to its *IV*. If, however, six months remain to expiration, then the price of the call should be greater and the *TVP* positive; if nine months remain, then the *TVP* should be even greater. In addition to the intuitive reasoning, an arbitrage argument also can be used to establish that the price of the call is greater with a greater time to expiration (this condition is also governed by an arbitrage).

Combined, the *IV* and the *TVP* show that two factors influencing the price of a call, C_t, are the underlying stock's price and the time to expiration:

$$C_t = IV + TVP$$

Call Price Curve

The relationship between C_t and the *TVP* and *IV* is shown graphically in Exhibit 16.12. In the exhibit, graphs plotting the call prices and the *IV*s (on the vertical axis) against P&G stock prices (on the horizontal axis) are shown for an 80 P&G call option. The IV line shows the linear relationship between the *IV* and the stock price. The line emanates from a horizontal intercept equal to the exercise price. When the price of the stock is equal to or less than the exercise price of $80, the *IV* is equal to zero; when the stock is priced at S_t = $85, the *IV* is $5; when S_t = $90, the IV = $10, and so on. The *IV* line, in turn, serves as a reference for the nonlinear call price curves. As we just noted, arbitrageurs ensure that the call price curve cannot go below the *IV* line. Furthermore, the *IV* line would be the call price curve if we are at expiration since the *TVP* = 0 and thus C_T = *IV*. The call price curves in Exhibit 16.12 show the positive relationship between C_t and S_t. The vertical distance between a curve and the *IV* line, in turn, measures the *TVP*. Thus, the call price curve shown with one year to expiration has a call price of $1.50 when the stock is below its exercise price at S_t = $70: Its *IV* = 0 and *TVP* = $1.50. When the stock is trading at its exercise price of $80, the call is priced at $4, the *IV* = 0, and the *TVP* = $4, and when the stock is at $85, the call is at $7, the *IV* = $5, and the *TVP* = $2. The call price curve for the six-month option is below the one-year call price curve, reflecting the fact that the call premium decreases as the time to expiration decreases.

EXHIBIT 16.12 Call and Stock Price Relation for P&G Call Option with X = $80

Middle Graph: Call Price Curve for Call with Six-Month Expiration

Upper Graph: Call Price Curve for Call with One-Year Expiration

45-Degree Line: Intrinsic Value (*IV*)

Bloomberg OV Screen

In summary, the graphs in Exhibit 16.12 show (1) that a direct relationship exists between the price of the call and the stock price, as reflected by the positively sloped call price curves; (2) that the call will be priced above its *IV*, as shown by the call price curves being above the *IV* line; and (3) the price of the call will be greater the longer the time to expiration, as reflected by the distance between call price curves with different expiration periods. Finally, it should be noted that the slopes of the call price curves approach the slope of the *IV* line when the stock price is relatively high (known as a *deep-in-the-money* *call*), and the slope approaches zero (flat) when the price of the stock is relatively low (a *deep-out-of-the-money call*).

Variability

The call price curve illustrates the positive relation between a call price and the underlying security price and the time to expiration. An option's price also depends on the volatility of the underlying security.

Since a long call position is characterized by unlimited profits if the underlying security increases but limited losses if it decreases, a call holder would prefer more volatility rather than less. Specifically, greater variability suggests, on the one hand, a given likelihood that the security will increase substantially in price, causing the call to be more valuable. On the other hand, greater volatility also suggests a given likelihood that the security price will decrease substantially. However, given that a call's losses are limited to just the premium when the security price is equal to the exercise price or less, the extent of the price decrease would be inconsequential to the call holder. Thus, the market will value a call option on a more volatile security greater than a call on one with lower variability.

The positive relationship between a call's premium and its underlying security's volatility is illustrated in Exhibit 16.13. The exhibit shows $100 call options on stocks A and B. As shown in the exhibit, Stock A is trading at $100 and has a variability characterized by an equal chance it will either increase by 10 percent or decrease by 10 percent by the end of the period (assume these are the only possibilities). Stock B, in turn, is shown trading at $100 and has a variability characterized by an equal chance it will either increase or decrease by 20 percent by the end of the period. Given the variability of the underlying stocks, the *IV* of the call option on Stock B would be either $20 or 0 at the end of the period, compared to possible values of only $10 and 0 for the call on Stock A. Since, Stock B's call cannot perform worse than Stock A's call, and can do better, it follows there would be a higher demand and therefore price for the call option on Stock B than the call on Stock A. Thus, given the limited loss characteristic of an option, the more volatile the underlying security, the more valuable the option, all other factors being equal.

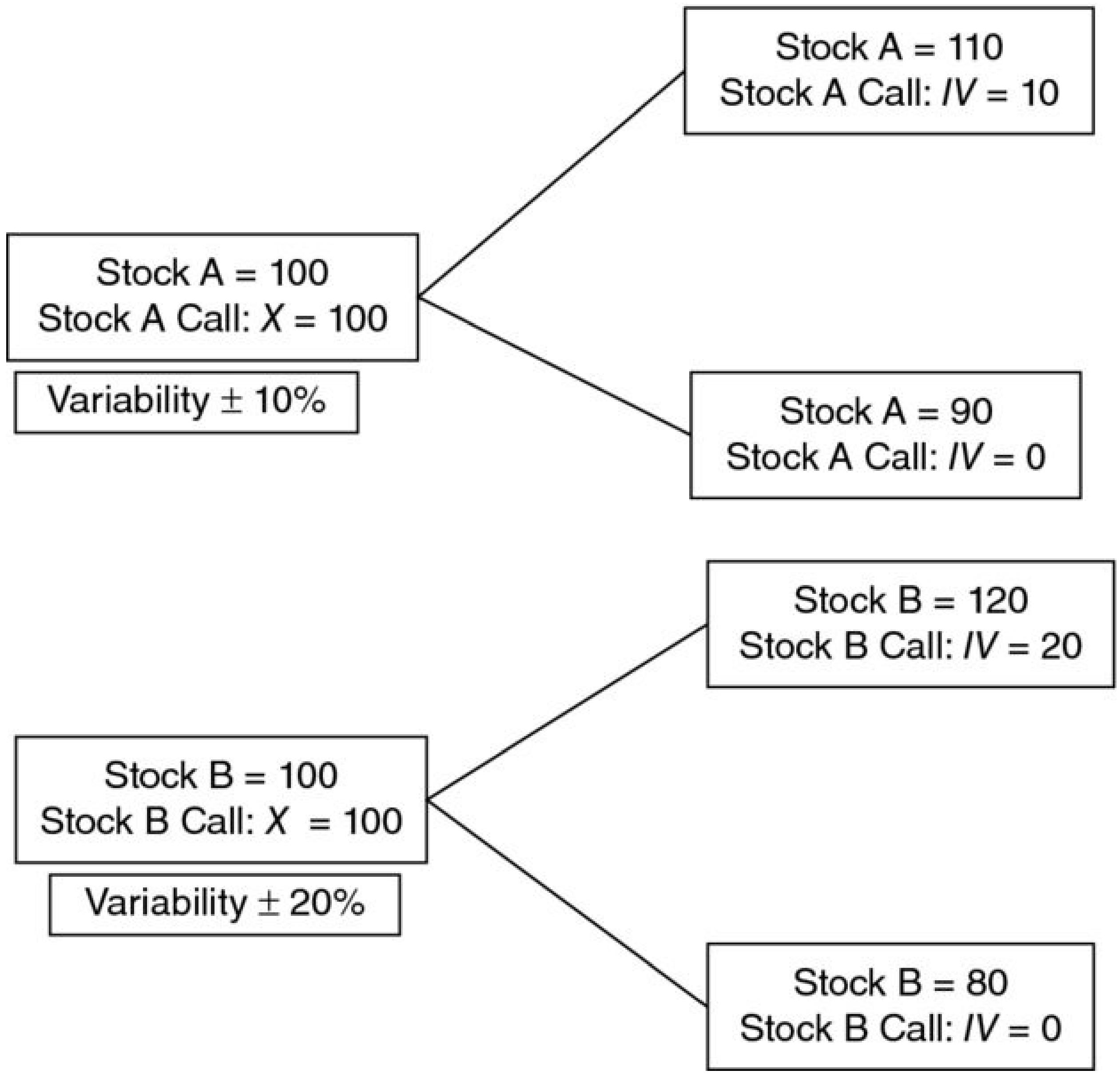


EXHIBIT 16.13 Price and Variability Relation

Put Price Relations

Analogous to calls, the price of a put at a given point in time prior to expiration (P_t) also can be explained by reference to its *IV* and *TVP*. In the case of puts, the *IV* is defined as the maximum of the difference between the exercise price and the stock price or zero:

$$IV = \text{Max}[X - S_t, 0]$$

Similar to calls, in-the-money, on-the-money, and out-of-the-money puts are defined as follows:

Type	Condition	Example
In-the-Money:	$X > S_t \Rightarrow IV > 0$	\$80 > \$70 => *IV* = \$10
On-the-Money:	$X = S_t \Rightarrow IV = 0$	\$80 = \$80 => *IV* = 0
Out-of-the-Money:	$X < S_t \Rightarrow IV = 0$	\$80 < \$90 => *IV* = 0

Like call options, the *IV* of an American put option defines a boundary condition in which the put has to trade at a price at least equal to its *IV*: $P_t \geq \text{Max}[X - S_t, 0]$. If this condition does not hold, an arbitrageur could buy the put, the underlying stock, and exercise to earn a riskless profit. For example, suppose P&G stock is trading at \$70 and a P&G 80 put was trading at \$9, below its *IV* of \$10. Arbitrageurs could realize risk-free profits by (1) buying the put at \$9, (2) buying P&G stock for \$70, and (3) immediately exercising the put, selling the stock on the put for 80. Doing this, the arbitrageur would realize a risk-free profit of \$1:

$S_t = 70$, $X = 80$, $P_t = 9$	
Position	**Cash Flow**
Buy P&G 80 Put for 9	−9
Buy P&G Stock for 70 in the Market	−70
Exercise P&G 80 Put:	
(Sell Stock on the put for $X = 80$)	+80
Profit	+1

As in the case of calls, arbitrageurs pursuing this strategy would increase the demand for puts until the put price was equal to at least the $10 difference between the exercise and stock prices. Thus, in the absence of arbitrage, an American put would have to trade at a price at least equal to its *IV*.

Similar to call options, the *TVP* for the put is defined as:

$$TVP = P_t - IV$$

Thus, the price of the put can be explained by the time to expiration and the stock price in terms of the put's *TVP* and *IV*:

$$P_t = IV + TVP$$

Put Price Curve

Graphically, the put and stock price relationships are shown in Exhibit 16.14. The exhibit shows two negatively sloped put-price curves with different exercise periods, and a negatively sloped *IV* line going from the horizontal intercept (where $S_t = X$) to the vertical intercept where the *IV* is equal to the exercise price when the stock is trading at zero (i.e., $IV = X$, when $S_t = 0$). The graphs show (1) the price of the put increases as the price of the underlying stock decreases, since the put's *IV* is greater the lower the stock price; (2) the price of the put is above its *IV* with time remaining to expiration, else arbitrage opportunities would ultimately push the price up to equal the *IV*; (3) the greater the time to expiration, the higher the *TVP* and thus the greater the put price; and (4) the slope of the put price curve approaches the slope of the *IV* line for relatively low stock prices (*deep-in-the-money puts*) and approaches zero for relatively large stock prices (*deep-out-of-the-money puts*).

EXHIBIT 16.14 Put and Stock Price Relation for P&G Put Option with *X* = 80

Middle Graph: Put Price Curve for Put with Six-Month Expiration

Upper Graph: Put Price Curve for Put with One-Year Expiration

Negative 45-Degree Line: Intrinsic Value (*IV*)

Bloomberg OV Screen

Variability

Like calls, the price of a put option depends not only on the underlying security price and time to expiration, but also on the volatility of the underlying security. Since put losses are limited to the premium when the price of the underlying security is greater than or equal to the exercise price, put buyers, like call buyers, will value puts on securities with greater variability more than those with lower variability.

Put-Call Parity

Consider a strategy of buying a share of stock for $50 and a put on the stock with an exercise price of $50. The cash flow from this portfolio at expiration is shown in Exhibit 16.15. As shown in Column 7, this stock and put portfolio has a minimum value of $50 (the exercise price) for $S_T \leq \$50$, and a value equal to the stock for $S_T > \$50$. Thus, an investor who purchased the stock some time ago could eliminate the downside risk of the stock by buying a put. In this case, the stock value has been "insured" not to fall below $50, the exercise price on the put. A combined stock and put position such as this is known as a *portfolio insurance* strategy or *stock insurance* strategy. Portfolio insurance represents an example of how options can be used by hedgers.

Cash Flows at Expiration						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
S_T	Long Call (X = 50)	Bond	Bond and Call Portfolio (3) + (4)	Long Put X = 50	Stock	Stock and Put Portfolio (5) + (6)
$30	$ 0	$50	$50	$20	$30	$50
40	0	50	50	10	40	50
50	0	50	50	0	50	50
60	10	50	60	0	60	60
70	20	50	70	0	70	70

EXHIBIT 16.15 Cash Flows on Call, Put, Stock, and Bond Positions at Expiration

Given the values of the stock and put portfolio, consider now a portfolio consisting of a bond with a face value of $50 and a 50 call on the stock. As shown in column 4 of Exhibit 16.15, the values of this portfolio at time *T* are identical to the stock and put portfolio's values at each stock price. If the stock appreciates, the call becomes more valuable and the return on the bond is enhanced by the appreciation in the call price. On the other hand, if the stock falls below the exercise price, the call is worthless and the portfolio simply is equal to the face value of the bond ($50). A bond and call portfolio such as this is referred to as a *fiduciary call*, and it can be used as a substitute for buying the stock and put. The equality between the stock-put portfolio and the bond-call portfolio may be expressed algebraically as:

$$S_t + P_t = C_t + B_t$$

This expression is commonly referred to as *put-call parity*. Since the two portfolios have exactly the same cash flows at expiration, their values at any time *t* must be identical, else arbitrage opportunities will exist. For example, if the bond-call combination is cheaper than the stock-put portfolio, an arbitrageur can earn a profit without taking risk and without investing any of her own money. To expedite the strategy, the arbitrageur would have to buy the cheap portfolio (bond and call) and sell the expensive one (stock and put). The put-call parity condition is governed by the *law of one price*. This law says that in the absence of arbitrage, any investments that yield identical cash flows must be equally priced.

Option Exchanges

As with all exchanges, the primary function of derivative exchanges offering options is to provide marketability to option contracts by linking brokers and dealers, standardizing contracts, establishing trading rules and procedures, guaranteeing and intermediating contracts through a clearinghouse, and providing continuous trading through electronic matching or with market makers, specialists, and locals.

Standardization

The option exchanges standardize contracts by setting expiration dates, exercise prices, and contract sizes on options. The expiration dates on options are defined in terms of an expiration cycle. For example, the March cycle has expiration months of March, June, September, and December. In a three-month option cycle, only the options with the three nearest expiration months trade at any time. Thus, as an option expires, the exchange introduces a new option. The exchanges also offer longer maturity contracts called LEAPS. On many option contracts, the expiration day is the Saturday after the third Friday of the expiration month; the last day on which the expiring option trades, however, is Friday. In addition to setting the expiration date, the exchanges also choose the exercise prices for each option, with as many as six strike prices associated with each option when an option cycle begins. Once an option with a specific exercise price has been introduced, it will remain listed until its expiration date. The exchange can, however, introduce new options with different exercise prices at any time.

The Option Clearing Corporation

To make derivative contracts more marketable, derivative exchanges provide a clearinghouse (CH) or *option clearing corporation* (OCC), as it is referred to on the option exchange. In the case of options, the OCC intermediates each transaction that takes place on the exchange and guarantees that all option writers fulfill the terms of their options if they are assigned. In addition, the OCC also manages option exercises, receiving notices and assigning corresponding positions to clearing members.

As an intermediary, the OCC functions by breaking up each option trade. After a buyer and seller complete an option trade, the OCC steps in and becomes the effective buyer to the option seller and the effective seller to the option buyer. At that point, there is no longer any relationship between the original buyer and seller. If the buyer of the option decides to exercise, he does so by notifying the OCC (through his broker on the exchange). The OCC (who is the holder's effective option seller) will select one of the option sellers with a short position on the exercised security and assign that writer the obligation of fulfilling the terms of the exercise request.

By breaking up each option contract, the OCC makes it possible for option investors to close their positions before expiration. If a buyer (seller) of an option later becomes a seller (buyer) of the same option, the OCC's computer will note the offsetting position in the option investor's account and will therefore cancel both entries. For example, suppose in January, Investor A buys a March 50 call for 3 from Investor B. When the OCC breaks up the contract, it records Investor A's right to exercise with the OCC and Investor B's responsibility to sell ABC stock at 50 if a party long on the call contract decides to exercise and the OCC subsequently assigns B the responsibility. The transaction between A and B would lead to the following entry in the clearing firms records:

	January Clearinghouse Records for March 50 Call
1.	Investor A has the right to exercise.
2.	Investor B has responsibility.

Suppose that in early February, the price of ABC stock is trading at 60 and the price of the March ABC 50 call is trading at 12. Seeing profit potential, suppose instead of exercising, Investor A decides to close her call position by selling a March 50 call at 12 to Investor C. After the OCC breaks up this contract, its records would have a new entry showing Investor A with the responsibility of selling ABC stock at X = \$50 if assigned. This entry, however, would cancel out Investor A's original entry, giving her the right to buy ABC stock at X = \$50:

	February Clearinghouse Records for March ABC 50 Call	
1.	Investor A has the right to exercise.	
2.	Investor B has responsibility.	Closed
3.	Investor C has the right to exercise.	
4.	Investor A has responsibility.	

The OCC would accordingly close Investor A's position. Thus, Investor A bought the call for 3 and then closed her position by simply selling the call for 12. Her call sale, in turn, represents an offsetting position and is referred to as an *offset* or *closing sale*.

If a writer also wanted to close his position at this date, he could do so by simply buying a March ABC 50 call option. For example, suppose Investor B feared that ABC stock would continue to increase and therefore decided to close his short position by buying a March ABC 50 call at 12 from Investor D. After this transaction, the OCC would again step in, break up the contract, and enter Investor B's and D's positions on its records. The OCC's records would now show a new entry in which Investor B has the right to buy ABC at 50. This entry, in turn, would cancel Investor B's previous entry in which he had a responsibility to sell ABC at 50 if assigned. The offsetting positions (the right to buy and the obligation to sell) cancel each other, and the OCC computer system simply erases both entries.

February Clearinghouse Records for March ABC 50 Call

1. Investor B has responsibility.
2. Investor C has the right to exercise.
3. Investor B has the right to exercise.
4. Investor D has responsibility.

Closed

Since Investor B's second transaction serves to close his opening position, it is referred to as a *closing purchase*. In this case, Investor B loses 9 by closing: selling the call for 3 and buying it back for 12.

Operationally, the OCC functions through its members. Referred to as clearing firms, these members are typically investment firms that are members of the exchange. Each one maintains an account with the OCC, records and keeps track of the positions for each option buyer and seller the OCC places with it, maintains all margin positions, and contributes to the special fund used to guarantee assignment. To recapitulate, by breaking up each transaction, the OCC provides marketability to options by making it easier for investors to close their positions. The OCC also enhances the marketability of option contracts by guaranteeing that the terms of a contract will be fulfilled if a holder exercises.

Margin Requirements and Trading Costs

To secure the OCCs underlying positions, exchange-traded option contracts have initial and maintenance margin requirements. The margin requirements on options apply only to the option writer. On most exchanges, the initial margin is the amount of cash or cash equivalents that must be deposited by the writer. In addition to the initial margin, the writer also has a maintenance margin requirement with the brokerage firm in which he has to keep the value of his account equal to certain percentage of the initial margin value. Thus, if the value of an option position moves against the writer, he is required to deposit additional cash or cash equivalents to satisfy his maintenance requirement.

Through the option exchanges, brokers, dealers, market makers, specialists, and the OCC have created a network whereby an investor can buy and sell options in a matter of minutes. The cost of maintaining this complex system is paid for by investors through the commission costs they pay to their brokers, the bid-ask spread investors pay to market makers or specialists when they set up and then later close their positions, and the fees charged by the clearing firms of the OCC that are usually included in the brokerage commission and paid by their brokers.

Types of Option Transactions

The OCC provides marketability by making it possible for option investors to close their positions instead of exercising. In general, there are four types of trades investors of an exchange-traded option can make: opening, expiring, exercising, and closing transactions. The *opening transaction* occurs when investors initially buy or sell an option. An *expiring transaction,* in turn, is allowing the option to expire: that is, doing nothing when the expiration date arrives because the option is worthless (out of the money). If it is profitable, a holder can exercise. Finally, holders or writers of options can close their positions with *offsetting* or *closing transactions* or orders.

As a general rule, option holders should close their positions rather than exercise. If there is some time to expiration, an option holder who sells her option will receive a price that exceeds the exercise value: that is, if the holder sells the option, she will receive a price that is equal to an *IV* plus a *TVP*; if she exercises, however, her exercise value is only equal to the *IV*. As a result, by exercising instead of closing, she loses the *TVP*. Thus, an option holder in most cases should close her position instead of exercising. There are some exceptions to the general rule of closing instead of exercising. For example, if an American option on a stock that was to pay a high dividend that exceeded the *TVP* on the option, then it would be advantageous to exercise.

Since many options are closed, the amount of trading and thus the marketability of a particular option can be determined by ascertaining the number of option contracts that are outstanding at a given point in time. The number of option contracts outstanding is referred to as *open interest*. Thus, in terms of closing transactions, open interest represents the number of closing transactions on an option that could be made before it expires. The exchange, in turn, keeps track of the amount of opening and closing transactions that occur. For example, an opening order to buy 5 calls would increase open interest by 5, and a closing order to sell 5 calls would lower open interest by 5.

Stock Index Options

In March 1983, the CBOE introduced an option on the S&P 100. Because of its hedging uses by institutional investors, this option quickly became one of the most highly traded options. In late April 1983, the American Stock Exchange began offering trading on an option on the Major Market Index (MMI), an index similar to the Dow Jones Average. The introduction of the AMEX's option soon was followed by the New York Stock Exchange's listing of the NYSE stock index option and the Philadelphia exchange's Value Line index option (index of 1,700 stocks) and the National Over-the-Counter index option (index of 100 OTC stocks). Today, the most popular index options include options on the Dow Jones Average (DJX), Nasdaq (NDX), Russell 2000 (RUT), S&P 100 (OEX), and the S&P 500 (SPX).

Theoretically, an index option can be thought of as an option to buy (call) or to sell (put) a portfolio of stocks composing the index in their correct proportions. Unlike stock options, index options have a *cash settlement* feature. When such an option is exercised, the assigned writer pays the exercising holder the difference between the exercise price and the spot index at the close of trading on the exercising day. Thus, an index option can be viewed as an option giving the holder the right to purchase (call) or sell (put) cash at a specific exercise price:

- **Definition**: A call option on a stock index gives the holder the right to purchase an amount of cash equal to the closing spot index (S_t) on the exercising day at the call's exercise price. To settle, the exercising holder receives a cash settlement of $S_t - X$ from the assigned writer.

For example, a May 1,700 S&P 500 call gives the holder the right to buy cash equal to the closing spot index on the exercising day for $1,700 (as discussed below, there also is a multiplier). If the holder exercises when the spot index is $1,800, he in effect is exercising the right to buy $1,800 of cash for X = $1,700. With cash settlement, the assigned writer simply pays the holder $100.

The put option on a stock index, on the other hand, gives the holder the right to sell cash equal to the spot index value:

- **Definition**: A put option on a stock index gives the holder the right to sell cash equal to the closing spot index on the exercising date at the put's exercise price. To settle, the exercising holder receives a cash settlement amount of $X - S_t$ from the assigned writer.

Thus, the holder of a May 1,700 S&P 500 put who exercises the put when the spot index is at 1,600 could view exercising as the equivalent to selling $1,600 cash to the assigned writer for $1,700. The writer would settle by paying the holder $X - S_t$ = $100.

The cash settlement feature of index options is one characteristic that differentiates them from stock options. Several other differentiating features of index options should be noted. First, the size of an index option is equal to a multiple of the index value. The S&P 100 and S&P 500 index options, for example, have contract multiples of $100. Thus, the actual exercise price on the above May 1,700 put contract on the S&P 500 is $170,000 = (1,700)($100). Second, the expiration features on many index options are similar to stock options, with most expiring on the third Friday of the expiration month. However, some index options have a shorter expiration cycle consisting of the current month, the next month, and third month from the present. Third, when an index option is exercised, the closing value of the spot index on the exercising day is used to determine the cash settlement. Since the spot index is computed continuously throughout the day, it is possible for a holder to exercise an in-the-money call early in the day, only to have it closed at the end of the day out of the money (in such a case the holder pays the writer the difference between X and S_t). Thus, an index option holder should wait until late in the day before giving his exercise notice. The assigned writer, in turn, is notified of the option assignment on the subsequent business day, at which time he is required to pay the difference in the exercise price and the closing index price. Fourth, a number of index options are European. Fifth, the tax treatment on index option positions differs from stock options in that all realized and unrealized gains on index options that occur during the year are subject to taxes, and all realized and unrealized losses occurring during the year can offset an investor's capital gains. Finally, the margin requirements for index options are similar to those for stock options, except for covered write positions, which have the same margin requirements as naked index option positions.

Managing Stock Portfolios with Index Options

One of the important uses of stock index options is in providing portfolio insurance. As previously noted, portfolio or stock insurance is combining a stock and put position. When applied to stock portfolios, it is a hedging strategy in which an equity portfolio manager protects the future value of her fund by buying index put options. The index put options, in turn, provide downside protection against a stock market decline, while allowing the fund to grow if the market increases.

To illustrate, consider the case of an equity fund manager who plans to sell a portion of a stock portfolio in September to meet an anticipated liquidity need. Suppose the portfolio that the manager plans to sell is well-diversified and highly correlated with the S&P 500, has a beta of 1.25, and currently is worth V_0 = \$50 million. Suppose the market, as measured by the spot S&P 500, is currently at 1,250 and that the manager expects a bullish market to prevail in the future with the S&P 500 rising. As a result, the manager expects to benefit from selling her portfolio in September at a higher value. At the same time, however, suppose the manager is also concerned that the market could be lower in September, and she does not want to risk selling the portfolio in a market with the index lower than 1,250. Suppose the CBOE has a September S&P 500 put option with an exercise price of 1,250 and multiplier of 100 that is trading at 50. As a strategy to lock in a minimum value from the portfolio sale if the market decreases, while obtaining a higher portfolio value if the market increases, suppose the manager decides to set up a portfolio insurance strategy by buying September 1,250 S&P 500 puts. To form the portfolio insurance position, the manager would need to buy 500 September S&P 500 puts at a cost of \$2.5 million:

$$N_p = \beta \frac{V_0}{X}$$

$$N_p = 1.25\,\frac{\$50{,}000{,}000}{(1{,}250)(\$100)} = 500 \text{ puts}$$

$$\text{Cost} = (500)(\$100)(50) = \$2{,}500{,}000$$

Exhibit 16.16 shows for five possible spot index values ranging from 1,000 to 1,500 the manager's revenue from selling the portfolio at the September expiration date and closing her puts by selling them at their intrinsic values. Note that for each index value shown in column 1, there is a corresponding portfolio value (shown in column 4) that reflects the proportional change in the market and the portfolio beta of

1.25. For example, if the spot index were at 1,000 at expiration, then the market as measured by the proportional change in the index would have decreased by 20 percent from its January level of 1,250 [−20% = (1,000–1,250)/1,250]. Since the well-diversified portfolio has a beta of 1.25, it would have decreased by 25 percent [β(%Δ S&P 500) = 1.25(−0.20) = −0.25], and the portfolio would, in turn, be worth only 75 percent of its January value of $50 million ($37.5 million). Thus, if the market were at 1,000, the corresponding portfolio value would be $37.5M ($37.5M = [1 + β (Proportional Δ S&P 500)]V_0 = [(1 +(−1.25)(0.20)] $50M). On the other hand, if the spot S&P 500 index were at 1,500 at the September expiration, then the market would have increased by 20 percent [= (1,500 − 1,250)/1,250] and the portfolio would have increased by 25 percent [1.25(0.20)] to equal $62.5 million [= 1.25 ($50M)]. Thus, when the market is at 1,500, the portfolio's corresponding value is $62.5 million. Given the corresponding portfolio values, column 5 in Exhibit 16.16 shows the intrinsic values of the S&P 500 put corresponding to the spot index values, and column 6 shows the corresponding cash flows that would be received by the portfolio manager from selling the 500 expiring September index puts at their intrinsic values. As shown in the exhibit, if the spot S&P 500 is less than 1,250 at expiration, then the manager would realize a positive cash flow from selling her index puts, with the put revenue increasing proportional to the decreases in the portfolio values, providing, in turn, the requisite protection in value. On the other hand, if the S&P 500 spot index is equal to or greater than 1,250, the manager's put options would be worthless, but her revenue from selling the portfolio would be greater, the greater the index. Thus, if the market were 1,250 or less at expiration, then the value of the hedged portfolio (stock portfolio value plus put values) would be $50 million; if the market were above 1,250, then the value of the hedged portfolio would increase as the market rises. Thus, for the $2.5 million cost of the put options, the fund manager has attained a $50 million floor for the value of the portfolio, while benefiting with greater portfolio values if the market increases.

Portfolio Hedged with S&P 500 Index Puts

Portfolio: Initial Value = $50M, β = 1.25

S&P 500 Put: *X* = 1,250, Multiplier = 100, Premium = 50

Hedge: 500 Puts; Cost = (500)(50)($100) = $2.5 million

1	2	3	4	5	6	7
S&P 500 Spot Index	**Proportional Change in the Market**	**Proportional Change in the Portfolio**	**Portfolio Value**	**Put Value at *T***	**Value of Put Investment**	**Hedged Portfolio Value**
S_T	$g = (S_T - 1{,}250)/1{,}250$	$\beta g = 1.25g$	$V_T = (1+\beta g)\$50M$	$P_T = IV = Max[1{,}250 - S_T, 0]$	$CF = 500(\$100) P_T$	**Column 4 + Column 6**
1,000	−0.20	−0.250	$37,500,000	250	$12,500,000	$50,000,000
1,125	−0.10	−0.125	$43,750,000	125	$6,250,000	$50,000,000
1,250	0.00	0.000	$50,000,000	0	$0	$50,000,000
1,375	0.10	0.125	$56,250,000	0	$0	$56,250,000
1,500	0.20	0.250	$62,500,000	0	$0	$62,500,000

EXHIBIT 16.16 Stock Portfolio Hedged with S&P 500 Puts

In addition to protecting the value of a portfolio, index options also can be used to hedge the costs of future stock portfolio purchases. For example, suppose the above portfolio manager was anticipating a cash inflow of $50 million in September, which she planned to invest in a well-diversified portfolio with a beta of 1.25 that was currently worth $50 million when the current spot S&P 500 index was at 1,250. Suppose there was a September S&P 500 call option trading at 50 and that the manager was fearful of a bull market pushing stock prices up, increasing the cost of buying the well-diversified portfolio. To hedge against this, the manager could lock in a minimum cost of the portfolio of $50 million by purchasing 500 September 1,250 S&P 500 index calls at a cost of $2.5 million:

$$N_C = \beta \frac{V_0}{X}$$

$$N_C = 1.25 \frac{\$50{,}000{,}000}{(1{,}250)(\$100)} = 500 \text{ calls}$$

$$\text{Cost} = (500)(\$100)(50) = \$2{,}500{,}000$$

As shown in Exhibit 16.17, if the spot index is 1,250 or higher at expiration, then the corresponding cost of the portfolio would be higher, but those higher portfolio costs would be offset by profits from the index calls. For example, if the market were at 1,500 in September, then the well-diversified portfolio with a β of 1.25 would cost $62.5million; the additional $12.5 million cost of the portfolio would be offset, however, by the $12.5 million cash flow obtained from the selling of 500 September 1,250 index calls at their intrinsic value of 250. Thus, as shown in the exhibit, for index values of 1,250 or greater, the hedged costs of the portfolio would be $50 million. On the other hand, if the index is less than 1,250, the manager would be able to buy the well-diversified portfolio at a lower cost, with the losses on the index calls limited to just the premium. Thus, for the $2.5 million costs of the index call option, the manager is able to cap the maximum cost of the portfolio at $50 million, while still benefiting with lower costs if the market declines.

Portfolio Hedged with S&P 500 Index Calls Portfolio: Current Cost = \$50M, β = 1.25 S&P 500 Call: X = 1,250, Multiplier = 100, Premium = 50 Hedge: 500 Calls; Cost = (500)(50)(\$100) = \$2.5 million						
1	2	3	4	5	6	7
S&P 500 Spot Index	Proportional Change in the Market	Proportional Change in the Portfolio	Portfolio Cost	Call Value at T	Value of Call Investment	Hedged Portfolio Cost
S_T	$g = (S_T - 1{,}250)/1{,}250$	$\beta g = 1.25g$	$V_T = (1+\beta g)\$50M$	$C_T = IV = \text{Max}[S_T - 1{,}250, 0]$	$CF = 500(\$100)\,C_T$	Column 4 – Column 6
1,000	−0.20	−0.250	\$37,500,000	0	\$0	\$37,500,000
1,125	−0.10	−0.125	\$43,750,000	0	\$0	\$43,750,000
1,250	0.00	0.000	\$50,000,000	0	\$0	\$50,000,000

1,375	0.10	0.125	$56,250,000	125	$6,250,000	$50,000,000
1,500	0.20	0.250	$62,500,000	250	$12,500,000	$50,000,000

EXHIBIT 16.17 Stock Portfolio Purchase Hedged with S&P 500 Calls

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OSA: PORTFOLIO INSURANCE

IMPORTING EQUITY PORTFOLIOS INTO BLOOMBERG'S OPTION SCENARIO SCREEN

On the OSA screen, you can import a portfolio and then add option positions.

To evaluate a portfolio insurance position for a portfolio you created in PRTU do the following:

- OSA <Enter>.
- From the "Portfolio" dropdown, select a portfolio.
- From red "Positions" tab, click "Add Listed Options" and then enter SPX in upper left amber area box.
- Select options and then click 1<GO>.
- On OSA screen, click portfolio summary box to include all stocks and options.
- Scroll down to options and set the number of puts needed to insure the portfolio.
- Click "Scenario Chart" tab and input setting: y box: mkt. value, range, and evaluation dates.

See Bloomberg Web Exhibit 16.2.

Black-Scholes Option Pricing Model

We described earlier how the price of an option is a function of the underlying stock's price and volatility and the option's time to expiration. An option's price also depends on other factors such as the risk-free return, whether the option is American or European, and whether the underlying stock pays a dividend during the period. Option pricing models integrate many of the relationships to determine the equilibrium price of an option.

The two most widely used models for determining the equilibrium option price are the *Black and Scholes* (B-S) *option pricing model* (OPM) and the *binomial option pricing model* (BOPM). Black and Scholes derived their model in 1973 in a seminal paper in the *Journal of Political Economy*. The BOPM was derived by Cox, Ross, and Rubinstein (1979) and Rendleman and Bartter (1979). Each determines the equilibrium price of an option in terms of arbitrage forces. Such arbitrage models are based on the law of one price. For calls or puts, this price is found by equating the price of the call or put to the value of a replicating portfolio; that is, a portfolio constructed so that its possible cash flows are equal to the call's possible payouts. The major difference in the models emanates from the assumption each makes concerning the underlying stock price's fluctuations over time, statistically referred to as its stochastic (or random) stock process. In the BOPM, the time to expiration is partitioned into a discrete or finite number of periods, each with the same length. In each period, the stock is assumed to follow a binomial process in which it either increases or decreases. The model then determines the equilibrium price of the option in which the cash flows from an arbitrage strategy consisting of positions in the stock, call, and a bond that are zero for each discrete period. The B-S OPM, on the other hand, posits a continuous process in which the time intervals are partitioned into infinitely small periods, or equivalently, the number of periods to expiration is assumed to approach infinity. In this continuous model, the price of the option is determined by assuming that the same arbitrage strategy used in the BOPM is implemented and revised continuously. Thus, the BOPM should be viewed as a first approximation of the B-S OPM. As the lengths of the intervals in the BOPM are made smaller, the discrete process merges into the continuous one and the BOPM and the B-S OPM converge.

The mathematics used in deriving the B-S OPM (stochastic calculus and a heat exchange equation) are complex; in fact, part of the contribution of the BOPM is that it is simpler to derive, yet still yields the same solution as the B-S OPM for the case of large periods. The derivations of these models are presented in many derivative texts. The B-S model, however, is relatively easy to use.

B-S OPM Formula

The B-S formula for determining the equilibrium call and put prices is:

$$C_0^* = S_0 \mathrm{N}(d_1) - \left[\frac{X}{\mathrm{e}^{RT}}\right] \mathrm{N}(d_2)$$

$$P_0^* = -S_0(1 - \mathrm{N}(d_1)) + \left[\frac{X}{\mathrm{e}^{RT}}\right] (1 - \mathrm{N}(d_2))$$

$$d_1 = \frac{\ln(S_0/X) + (R + 0.5\sigma^2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

where:

- T = time to expiration expressed as a proportion of the year
- R = continuously compounded annual risk-free rate of return
- σ = annualized standard deviation of the underlying security's logarithmic return
- $\mathrm{N}(d_1)$, $\mathrm{N}(d_2)$ = cumulative normal probabilities

In the call and put equations, X/e^{RT} is the present value of the exercise price, $PV(X)$, continuously compounded. R is the continuously compounded annual risk-free rate. This rate can be found by taking the natural logarithm of 1 plus the simple annual rate on a risk-free security with a maturity equal to the call's expiration date. Thus, if 0.06 is the annual discrete rate, then the continuous compounded rate is $\ln(1 + 0.06) = 0.0583$; σ^2 is the annualized variance of the logarithmic return, $\ln(S_1/S_0)$. The cumulative normal probabilities, $N(d_1)$ and $N(d_2)$, are the probabilities that deviations of less than d_1 or d_2 will occur in a standard normal distribution with a zero mean and a standard deviation of 1. Tables provide such probabilities are found in many statistics and finance books. The following power function can be used instead of the table to obtain better estimations of $N(d_1)$ and $N(d_2)$:

$$
\begin{aligned}
\mathrm{N}(d) &= 1 - \mathrm{n}(d), \text{ for } d < 0 \\
\mathrm{N}(d) &= \mathrm{n}(d), \text{ for } d > 0
\end{aligned}
$$

where:

$$
\begin{aligned}
\mathrm{n}(d) &= 1 - 0.5[1 + 0.196854(|d|) + 0.115194(|d|)^2 \\
&\quad + 0.000344(|d|)^3 + 0.019527(|d|)^4]^{-4} \\
|d| &= \text{absolute value of } d.
\end{aligned}
$$

Example

Consider an ABC 50 call and an ABC 50 put that both expire in three months ($T = 0.25$). Suppose ABC stock is trading at \$45 and has an estimated annualized variance of 0.25 ($\sigma = 0.5$), and the continuously compounded annual risk-free rate is 6 percent. Using the B-S OPM, the value of the call would be \$2.88 and the value of the put would be \$7.13:

$$C_0^* = S_0\mathrm{N}(d_1) - \left[\frac{X}{\mathrm{e}^{RT}}\right]\mathrm{N}(d_2)$$

$$C_0^* = (\$45)(0.4066) - \left[\frac{\$50}{e^{(0.06)(0.25)}}\right](0.3131) = \$2.88$$

$$P_0^* = -S_0(1 - \mathrm{N}(d_1)) + \left[\frac{X}{\mathrm{e}^{RT}}\right](1 - \mathrm{N}(d_2))$$

$$P_0^* = -\$45(0.5934) + \left[\frac{\$50}{e^{(0.06)(0.25)}}\right](0.6869) = \$7.13$$

where:

$$d_1 = \frac{\ln(\$45/\$50) + [0.06 + 0.05(0.5)^2](0.25)}{0.5\sqrt{0.25}} = -0.2364$$

$$d_2 = -0.2364 - 0.5\sqrt{0.25} = -0.4864$$

$$\mathrm{N}(d_1) = \mathrm{N}(-0.2364) = 1 - [1 - 0.5[1 + 0.196854(0.2364) + 0.115194(0.2364)^2 + 0.000344(0.2364)^3 + 0.019527(0.2364)^4]^{-4}] = 0.4066$$

$$\mathrm{N}(d_2) = \mathrm{N}(-0.4864) = 1 - [1 - 0.5[1 + 0.196854(0.4864) + 0.115194(0.4864)^2 + 0.000344(0.4864)^3 + 0.019527(0.4864)^4]^{-4}] = 0.3131$$

Comparative Analysis

The B-S call and put prices depend on the underlying stock price, exercise price, time to expiration, risk-free rate and the stock's volatility: S, X, T, R, and σ. The impacts that changes in these parameter values have on the B-S OPM price also can be seen in terms of the simulation presented in Exhibit 16.18, in which combinations of the B-S OPM call values and stock prices are shown for different parameter values.

The first column in the upper table shows the call values given the parameter values used in the preceding example: $X = 50$, $T = 0.25$, $R = 0.06$, and $\sigma = 0.5$. For purposes of comparison, the other columns show the call and stock price relations generated with the same parameter values used in column 1, except for one variable: In column 2, $X = 40$; in column 3, $T = 0.5$; in column 4, $\sigma = 0.75$; and in column 5, $R = 0.08$.

Stock Price	**1** ***X*** **= 50** ***T*** **= 0.25** σ = 0.5 *R* = 0.06 C^*_0	**2** ***X*** **= 40** ***T*** **= 0.25** σ = 0.5 *R* = 0.06 C^*_0	**3** ***X*** **= 50** ***T*** **= 0.5** σ = 0.5 *R* = 0.06 C^*_0	**4** ***X*** **= 50** ***T*** **= 0.25** σ = 0.75 *R* = 0.06 C^*_0	**5** ***X*** **= 50** ***T*** **= 0.25** σ = 0.5 *R* = 0.08 C^*_0
$ 30	$ 0.0841	$ 0.5967	$ 0.5453	$ 0.6292	$ 0.0890
35	0.4163	1.9065	1.3751	1.5028	0.4328
40	1.2408	4.2399	2.8365	2.9852	1.2826
45	2.8756	7.5682	4.9626	5.1006	2.9550
50	5.2999	11.5935	7.6637	7.7452	5.4210
55	8.5584	16.0952	10.9683	10.9782	8.7103
60	12.3857	20.8355	14.6539	14.5768	12.5702
65	16.6919	25.7002	18.7114	18.5269	16.8996
70	21.2865	30.6342	23.0555	22.7703	21.5083

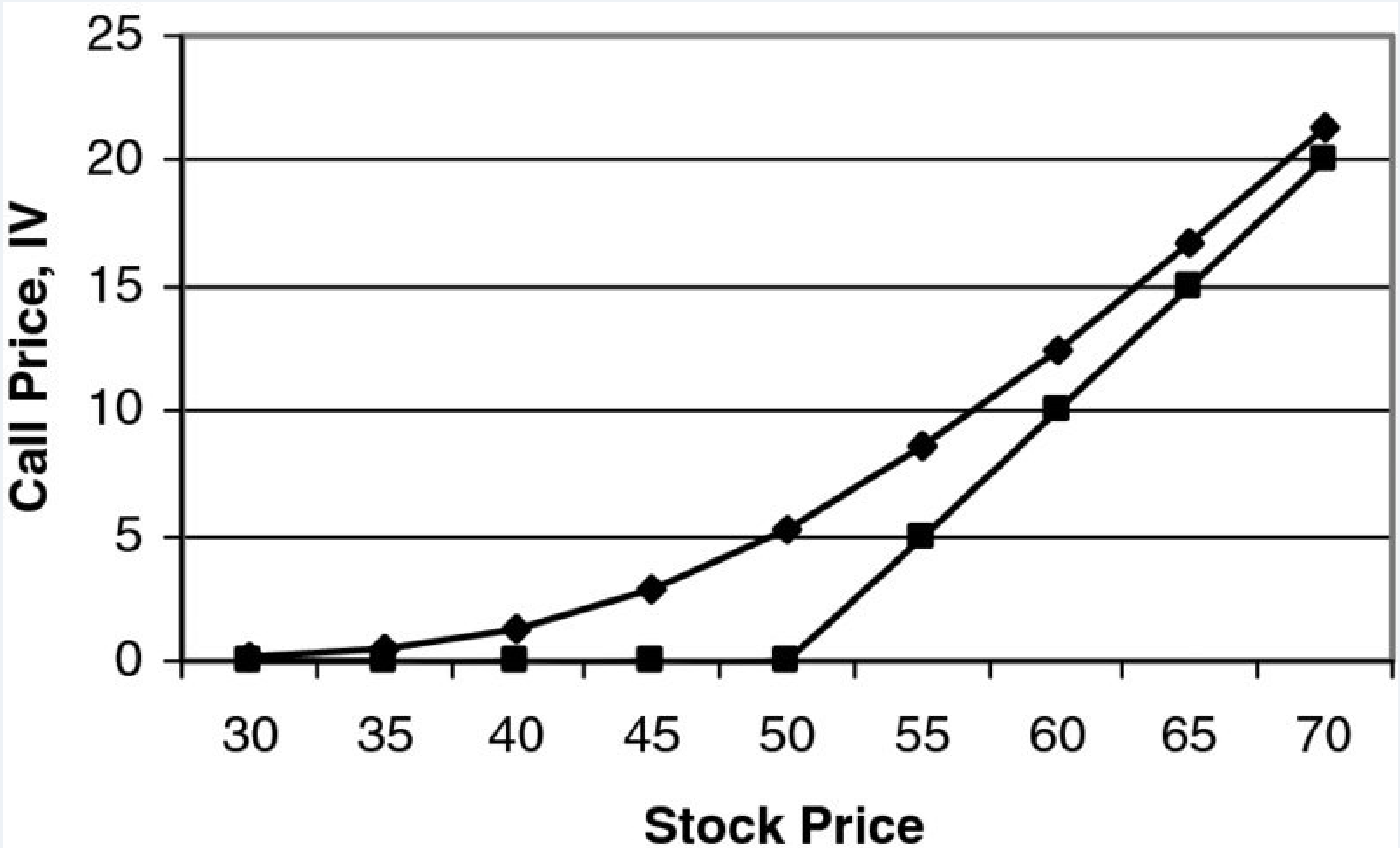

EXHIBIT 16.18 B-S OPM Call Price and Stock Price Relation Given Different Parameter Values

In examining the exhibit, note several of the intuitive relationships that were explained earlier. First, as shown in any of the columns, when the stock is relatively low and the call is deep out of the money, the B-S OPM yields a very low call price, but as we would expect, one that is nonnegative. As the price of the stock increases by equal increments, the OPM call prices increase at an increasing rate up to a point, with the values never being below the intrinsic value. Thus, over a range of stock prices, the B-S OPM yields a call and stock price relation that is nonlinear and satisfies a lower boundary condition. The nonlinear relationship also can be seen in Exhibit 16.19, where the B-S option call values and stock prices from column 1 are plotted. As shown, the slope of this B-S option price curve increases as the stock price increases, the curve does not yield negative values, and it is above the *IV* line.

	1 X = 50 T = 0.25 σ = 0.5 R = 0.06	**2 X = 40 T = 0.25** σ = 0.5 R = 0.06	**3 X = 50 T = 0.5** σ = 0.5 R = 0.06	**4 X = 50 T = 0.25** σ = 0.75 R = 0.06	**5 X = 50 T = 0.25** σ = 0.5 R = 0.08
Stock Price	P^*_0	P^*_0	P^*_0	P^*_0	P^*_0
$30	$19.3397	$10.0012	$19.0675	$19.8848	$19.0990
35	14.6719	6.3110	14.8973	15.7584	14.4428
40	10.4964	3.6444	11.3588	12.2408	10.2926
45	7.1312	1.9727	8.4848	9.3562	6.9650
50	4.5555	0.9979	6.1860	7.0008	4.4309
55	2.8140	0.4996	4.4905	5.2338	2.7203
60	1.6413	0.2400	3.1761	3.8324	1.5801
65	0.9475	0.1046	2.2337	2.7825	0.9095
70	0.5421	0.0387	1.5778	2.0259	0.5182

1 X = 50 T = 0.25	**2 X = 40 T = 0.25**	**3 X = 50 T = 0.5**	**4 X = 50 T = 0.25**	**5 X = 50 T = 0.25**
σ = 0.5 R = 0.06	σ = 0.5 R = 0.06	σ = 0.5 R = 0.06	σ = 0.75 R = 0.06	σ = 0.5 R = 0.08

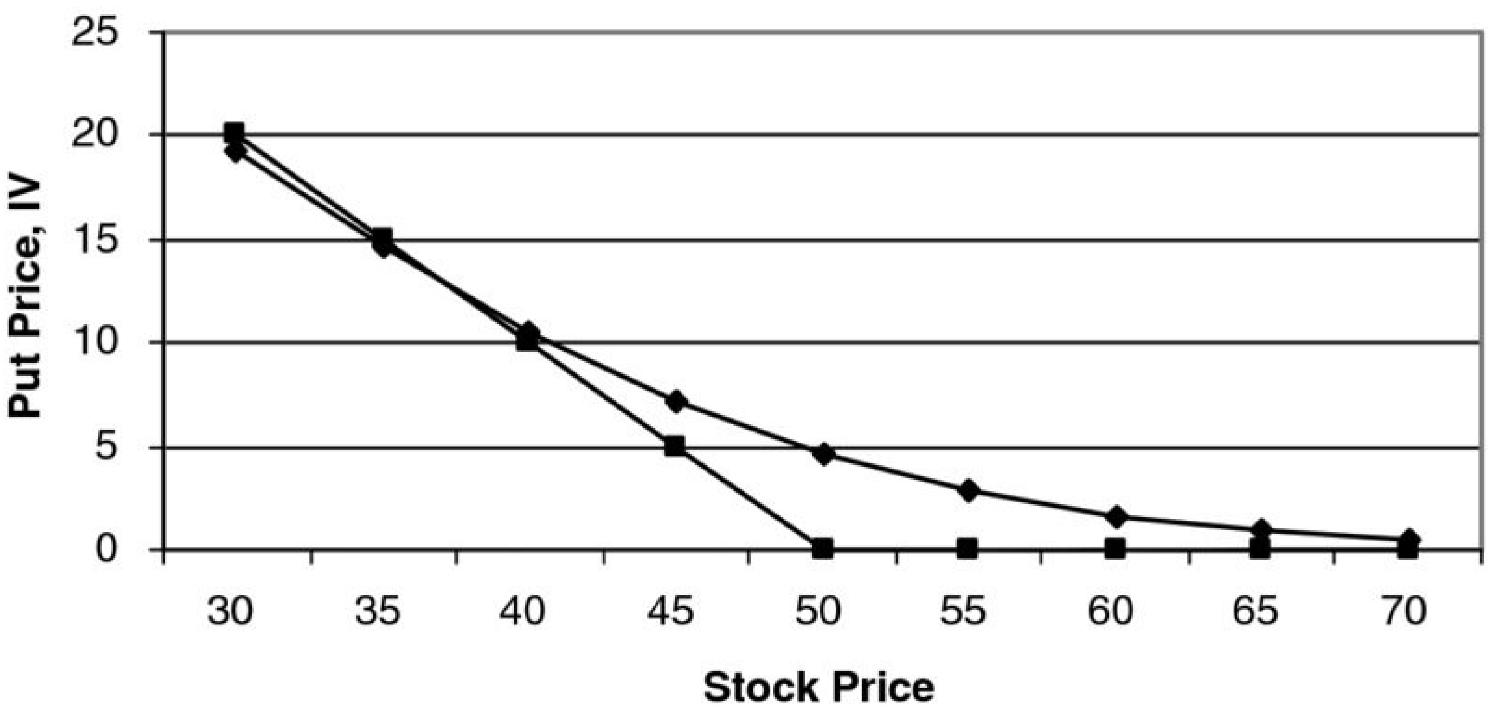

EXHIBIT 16.19 B-S OPM Put Price and Stock Price Relation Given Different Parameter Values

The slope of the curve is referred to as the option's *delta*. Delta is equal to N(d_1) in the B-S model. For a call, the delta ranges from 0 for deep-out-of-the-money calls to approximately 1 for deep-in-the-money ones. The nonlinear call and stock price relation also can be seen by the change in the slope of the B-S option price curve as the stock price increases. In option literature, the change in slope (i.e., delta) per small change in the stock price defines the option's *gamma* (it is the second-order partial derivative of the call price with respect to changes in the stock price).

Second, a comparison of columns 1 and 2 shows that for each stock price, higher call prices are associated with the call with the lower exercise price. Thus, as the exercise price decreases, the B-S OPM call price increases. Third, comparing column 3 with column 1 shows that as the B-S OPM call price increases, the greater the time to expiration. The change in an option's prices with respect to a small change in the time to expiration (with other factors held constant) is defined as the option's *theta*. Fourth, a comparison of columns 4 and 1 shows that the greater the stock's variability, the greater the call price. The change in the call price given a small change in the stock's variability is referred to as the option's *vega* (also called *kappa*). Last, comparing columns 1 and 5 shows the call price increases the greater the interest rate. The change in the call price given a small change in R is called the call's *rho*.

Exhibit 16.19 shows the combinations of the B-S put prices and stock prices for different parameters: X (column 2), T (column 3), σ (column 4), and R (column 5). In examining any of the columns in the table, observe the negative, nonlinear relationship between the B-S put price and the stock price (i.e., the put has a negative delta and nonzero gamma). Next, comparing columns 2 and 5 with column 1, observe that for each stock price, the greater the exercise price or the lower the interest rate, the greater the B-S put price. Finally, comparing columns 3 and 4 with column 1, observe that the greater the time to expiration or the greater the stock's variability, the greater the put price. Thus, the B-S put model captures the intuitive relationships described earlier. It should be noted that the B-S put model is unconstrained. That is, the B-S put model does not constrain the put value to being equal to at least its intrinsic value. Thus, for an in-the-money put, the premium can be less than its IV, as shown in column 1 when the stock is at $30. The possibility that $P^* < IV$ reflects the fact that the B-S model is limited to determining the price of a European put, in which negative time value premiums are possible.

Dividend Adjustments for the Black-Scholes Model

Dividends can cause the price of a call (put) to decrease (increase) on the stock's ex-dividend date and can lead to an early exercise if the option is American. The B-S OPM values European options without dividends. It therefore needs to be adjusted for dividends and for the possibility of early exercise possibility when dividends are expected. Two dividend adjustment models that use the B-S OPM are Fisher Black's pseudo-American call model, applicable to American calls when there are dividends, and Merton's continuous dividend yield approach. Both models are presented in many derivative texts.

Estimating the Black-Scholes Model

The B-S OPM is defined totally in terms of the stock price, exercise price, time to expiration, interest rate, and volatility. The first three variables are observable. The interest rate needs to be identified, and the stock's volatility needs to be estimated. In estimating the risk-free rate for the B-S OPM, the rate on a Treasury bill, commercial paper, or other money market security with a maturity equal to the option's expiration are typically used.

Two methods are often used to estimate the variance of the logarithmic return: calculating the stock's historical variance and solving for the stock's implied variance. A stock's historical variability is computed using a sample of historical stock prices (converted to logarithmic returns ($\ln(S_n/S_0)$)). The implied variance is that variance that equates the OPM's value to the market price. It is found iteratively, substituting different variance values into the B-S model until that variance is found that yields an OPM value equal to the market price. Theoretically, we should expect the implied variance for different options on the same stock to be the same. In practice, this does not occur. One way to select an implied variance is to use the arithmetic average for the different implied variances on the stock. A common approach among option traders is to select the volatility based on the option's *volatility smile* and its *volatility term structure*. A volatility smile is a plot of the implied volatilities given different exercise prices. The volatility term structure, in turn, refers to the relation between an option's implied volatility and the time to expiration. Option traders use *volatility surfaces* (graph of volatility against *T* and *X*) to help them determine the appropriate volatilities to use when pricing an option with either the B-S OPM or the binomial model.

BLOOMBERG OPTION PRICING SCREEN—OV/OVME

The Bloomberg OV screen calculates the price of an option using the Black-Scholes OPM or the Binomial (Trinomial). The user can input the variability or use the historical volatility or the implied volatility. The OV/OVME screen can be used to value existing options or an option created from an existing security. The screen shows the option's vega, theta, and rho values. The "Scenario" tab shows the price of the options given different stock price and times to expiration. The "Volatility" tab shows tables and graphs of volatility smiles, term structure, and surface. The models do incorporate dividend adjustments. Settings for dividend can be found from the "Data and Settings" tab.

See Bloomberg Web Exhibit 16.3.

Conclusion

In this chapter, we have provided an overview of options by defining option terms, examining option strategies, including portfolio insurance, looking at the functions of organized exchanges, and describing the features of the B-S OPM. Options are one of the important derivatives for speculating and hedging security and portfolio positions. In the next chapter, we examine the other important derivative—futures.

Web Site Information

- Information on the CBOE: www.cboe.com.
- Information on the Chicago Mercantile Exchange: http://www.cmegroup.com.
- U.S. Commodity Futures Trading Commission: http://www.cftc.gov.

Notes

1. As we will see later, most options are not exercised, but instead are closed by holders selling their contract and writers buying their contracts. As a starting point in developing a fundamental understanding of options, however, it is helpful to first examine what happens if the option is exercised.

2. In many of our examples, we assume calls and puts with the same terms are priced the same. We do this for simplicity. In most cases, however, calls and puts with the same terms are not priced equally.

3. The boundary condition for a European call is Max[S_t – $(X/(1 + R_f)^T$, 0]. The proof is found in many derivative texts. See Johnson, *Introduction to Derivatives* (2009).

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Bloomberg Exercises

1. Find descriptions, recent prices, and other information on different types of stock options: Ticker <Equity> <Enter>, click OMON. Screens to consider are DES, OTD, OMON, and OMST. To bring up an option's screen: option ticker <Equity> <Enter>.
2. Select a stock and bring up its equity screen: ticker <Equity> <Enter>). Using the Bloomberg OSA screen, select call and put options on the stock (“Positions” tab; “Add Listed Options”) and evaluate the following option strategies on the stock with a profit graph:
   1. Call purchase.
   2. Call sale.
   3. Put purchase.
   4. Put sale.
   5. Covered call write.
   6. Covered put write.
   7. Straddle purchase.

    8. Straddle sale.
    9. Simulated long position.
    10. Simulated short position.
3. Identify several option strategies that you would consider if you expected stock prices to increase in the next three months. Select an option and analyze your strategies using Bloomberg's OSA screen.
4. Identify several option strategies that you would consider if you expected stock prices to decrease in the next three months. Select an option and analyze your strategies using Bloomberg's OSA screen.
5. Identify several option strategies that you would consider if you expected stock prices to be stable over the next three months. Select an option and analyze your strategies using Bloomberg's OSA screen.
6. Select exchange call and put options on an index, and evaluate the following option strategies for different holding periods with a profit table and/or graph using the Bloomberg OSA function: call purchase, put purchase, straddle purchase, straddle sale, synthetic long position, or synthetic short position.
7. Determine B-S prices of call and put options on a selected stock using the Bloomberg OV/OVME screen. Examine the model's call and put values and stock price curve generated from Bloomberg. Use either Bloomberg defaulted values for the stock's volatility, risk-free rate, and dividends, or input your own.
8. Portfolio insurance: Use Bloomberg to construct an equity portfolio or select one you have already constructed. Determine the index put positions you would need to create a portfolio insurance strategy (consider the horizon period when you select the maturity of the option). Use OSA to generate a value graph of your hedged portfolio. Include screens in you answer and bullet points on key observations. For a guide, see Bloomberg exhibit box: “OSA: Portfolio Insurance.”