MANAGING FINANCIAL RISK

by Clifford W. Smith, Jr.,
University of Rochester,
Charles W. Smithson, Continental Bank,
and D. Sykes Wilford,
*Chase Manhattan Bank**

There is no doubt that the financial environment is a lot more risky today than it was in the 1950s and 1960s. With changes in some macroeconomic institutional structures—notably, the breakdown of the Bretton Woods agreement in 1972—have come dramatic increases in the volatility of interest rates, foreign exchange rates, and commodity prices.

Such increased volatility will not come as "news" to most corporate executives. Since the 1970s, many CEOs and CFOs have watched the profitability of their firms swing widely in response to large movements in exchange rates, interest rates, and commodity prices. What may be news, however, are the techniques and tools now available for measuring and managing such financial risks.

Recognition of the increased volatility of exchange rates, interest rates, and commodity prices should lead managers of the firm to ask three questions:

1. To what extent is my firm exposed to interest rates, foreign exchange rates, or commodity prices?
2. What financial tools are available for managing these exposures?
3. If my firm is significantly exposed, how do I use the financial tools to manage the exposure?

It is with these three questions that the following discussion deals.

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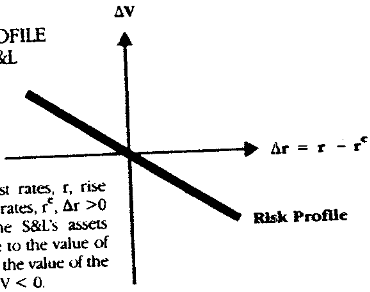
IDENTIFYING AND MEASURING FINANCIAL RISK

The Risk Profile

U.S. savings and loans (S&Ls) are a widely cited example of firms subject to interest rate risk. Because S&Ls typically fund long-lived assets (e.g., 30-year fixed-rate mortgages) with liabilities that reprice frequently (passbook deposits), their value is negatively related to interest rates. When interest rates rise, the value of S&Ls' assets declines significantly, but the value of their liabilities changes little. So, the value of shareholders' equity falls.

The resulting relation between interest rates and the value of S&Ls is portrayed graphically in a *risk profile* in Figure 1.

FIGURE 1
THE RISK PROFILE FOR A U.S. S&L



As actual interest rates, r, rise above expected rates, r^e, $\Delta r > 0$ the value of the S&L's assets declines relative to the value of its liabilities, so, the value of the firm declines, $\Delta V < 0$.

The negative slope reflects the inverse relation between the financial price—i.e., interest rates—and the value of the S&L. The precise measure of the exposure is reflected by the slope of the line; and it is a measure of the slope that the techniques described below will provide.

But before considering the size of the exposure, the first question is: How do we go about identifying such exposures? In the case of S&Ls, the exposure to interest rates is apparent from the firm's balance sheet; the mismatch of maturities between assets and liabilities is obvious. Many companies, however, have economic or "operating" exposures that are not reflected on their balance sheets. Take, for example, the vulnerability of building products firms to increases in interest rates. Increases in interest rates decrease the demand for building products. As sales and thus cash inflows decline—and to the extent that its costs and liabilities are fixed—the value of a building products firm declines.

We can make a similar observation about foreign exchange risk. In some instances, exposures are apparent. For example, a U.S. importer orders product from Germany and is expected to pay in Deutsche Marks (DM) for the products when they are delivered in 90 days. If, during those 90 days, the price of a DM rises—that is, the value of the dollar declines—the U.S. importer will have to pay more for the product. In this case, an increase in the price of the foreign currency leads to a decrease in the value of the importer.

Since 1972, firms have become adept at dealing with such transaction exposures.[1] However, a firm's exposure to foreign exchange rate risk can be more subtle; even firms that have no foreign receipts or payments may still be exposed to foreign exchange risk. If the dollar is strong, the dollar price of foreign products to U.S. consumers becomes cheaper and foreign firms make inroads into the U.S. market, thereby decreasing net cash flows to the U.S. producers and thus reducing their value. The reverse is true when the value of the dollar falls. Obvious for firms like automakers, this economic or competitive (or "strategic") risk is receiving more attention by the managers of other U.S. firms as well.[2]

Not surprisingly, the same relations appear with respect to commodity price risk. The exposures can be apparent: For example, as the price of oil rises, the costs for an airline rise; so rising oil prices are linked to falling firm values. Or, the exposures can be subtle. For example, a primary input in aluminum production is electric energy. Aluminum manufacturers in Iceland use electricity generated by that country's abundant geothermal energy. As the price of oil rises, the costs of competitors rise while the costs of Icelandic producers remain unchanged, thus improving the competitive position and increasing the value of Icelandic firms. It is when oil prices fall and competitors' costs decline that Icelandic producers worry.[3]

Financial price risk, then—whether caused by changes in interest rates, foreign exchange, or com-

1. A transaction exposure occurs when the firm has a payment or receipt in a currency other than its home currency. A translation exposure results when the value of foreign assets and liabilities must be converted into home currency values.

2. A case in point is Kodak, which has begun to manage "overall corporate performance in the long run." See Paul Dickens, "Daring to Hedge the Unhedgeable," *Euromoney Corporate Finance*, August 1988.

3. For this useful story about Icelandic aluminum producers, we are indebted to J. Nicholas Robinson of Chase Manhattan Bank.

TABLE 1
CALCULATION OF THE VALUE & DURATION OF THE BUSINESS LOAN

(1) Time to Receipt (Years)	(2) Cash Flow	(3) Discount Rate	(4) PV	(5) Weight	(6) Weight × Time
0.5	90	7.75%	86.70	0.22	0.11
1.0	90	8.00%	83.33	0.21	0.21
1.5	90	8.25%	79.91	0.20	0.31
2.0	90	8.35%	76.66	0.19	0.38
2.5	90	8.50%	73.40	0.18	0.45
			400.00 Present Value		1.45 Duration

modity prices—consists of more subtle economic exposures as well as the obvious balance sheet mismatches and transactional exposures. And the *risk profile* mentioned earlier, in order to provide a useful measure of a firm's overall economic exposure, must reflect the total effect of both kinds of price risk.

The question that naturally arises, then, is: How do you determine the slope of the risk profile? That is, how do you estimate the change in firm value expected to accompany a given change in a financial price ($\Delta V/\Delta P$)?

Quantifying Financial Risk: A Special Case

Financial institutions, particularly banks, were the first to devote significant attention to quantifying financial exposures. Our S&L example is admittedly an extreme case of interest rate exposure, even for a financial institution. Nevertheless, because some mismatch between the maturities of assets and liabilities almost inevitably occurs in the normal course of their business, all financial institutions generally face some degree of interest rate risk. To measure this exposure to interest rates, financial institutions rely on two techniques: gap and duration.

GAP: The method most financial corporations use to measure their exposure to interest rate changes is called the "maturity gap" approach.[4] The approach gets its name from a procedure designed to quantify the "gap" between the market values of rate-sensitive assets (RSA) and rate-sensitive liabilities (RSL)—that is, GAP = RSA − RSL.[5] The financial institution determines the "gapping period"—the period over which it wants to measure its interest rate sensitivity—say, 6 months, one year, five years, and so forth. Then, for each of these periods, it measures its gap as defined above. In the context of a gap model, changes in interest rates affect a financial institution's market value by changing the institution's Net Interest Income (NII). Hence, once the GAP is known, the impact on the firm of changes in the interest rate can be calculated as follows:

$$\Delta \mathbf{NII} = (\mathbf{GAP}) \times (\Delta \mathbf{r})$$

Duration: Some financial institutions use an alternative to the GAP approach called "duration analysis" to measure their interest rate exposure.[6] In essence, the duration of a financial instrument provides a measure of when on average the present value of the instrument is received.

For example, let's look at the duration of a business loan with a maturity of 2.5 years and a sinking fund. Because part of the value is received prior to maturity, the duration of the instrument is clearly less than 2.5 years. To find out how much less, we need to ask the question "When on average is the present value received?"

4. For a discussion of the maturity gap model, see Alden L. Toevs, "Measuring and Managing Interest Rate Risk: A Guide to Asset/Liability Models Used in Banks and Thrifts," Morgan Stanley Fixed Income Analytical Research Paper, October 1984. (An earlier version of this paper appeared in *Economic Review*, The Federal Reserve Bank of San Francisco, Spring, 1983.)

5. The assets and liabilities that are "rate sensitive" are those that will reprice during the gapping period.

6. For a discussion of duration, see George G. Kaufman, "Measuring and Managing Interest Rate Risk: A Primer," *Economic Perspectives*, Federal Reserve Bank of Chicago. See also Stephen Schaefer, "Immunisation and Duration: A Review of the Theory, Performance, and Applications," *Midland Corporate Finance Journal*, Vol. 2 No. 3, Fall 1984.

Table 1 provides an illustration. Columns 1-4 provide the present value of the bond. To determine *when* the present value will be received, on average, we need to calculate the weighted average time of receipt. Column 5 provides the weights. Multiplying these weights (column 5) by the times the cash flows are received (column 1) and summing gives the duration of this business loan—1.45 years.

The use of duration effectively converts a security into its zero-coupon equivalent. In addition, duration relates changes in interest rates to changes in the value of the security.[7] Specifically, duration permits us to express the percentage change in the value of the security in terms of the percentage change in the discount rate (1 + r) and the duration of the security, as follows:[8]

$$\frac{\Delta \mathbf{V}}{\mathbf{V}} = \frac{\Delta\,(\mathbf{1} + \mathbf{r})}{(\mathbf{1} + \mathbf{r})} \times \mathbf{D}$$

For example, if the duration of a security is 1.45 years, and the discount rate increases by 1 percent (that is, if $\Delta\ (1 + r)/(1 + r) = 0.01$), the market value of the 2.5 year business loan will decrease by 1.45 percent. The concept of duration, moreover, can be extended to provide a measure of the interest rate exposure of an entire bank or S&L.

Quantifying Financial Price Risk: The General Case

While gap and duration work well for financial institutions, these techniques offer little guidance in evaluating the interest rate sensitivity of a nonfinancial institution; and, neither gap nor duration is useful in examining a firm's sensitivity to movements in foreign exchange rates or commodity prices. What is needed is a more general method for quantifying financial price risk—a method that can handle firms other than financial institutions and financial exposures other than interest rates.

To get a measure of the responsiveness of the value of the firm to changes in the financial prices, we must first define a measure of the value of the firm. As with interest rate risk for financial institutions, this value measure could be a "flow" measure (gap analysis uses net interest income) or a "stock" measure (duration uses the market value of the portfolio).

Flow Measures. Within a specific firm, estimation of the sensitivity of income flows is an analysis that can be performed as part of the planning and budgeting process. The trade press suggests that some firms have begun using simulation models to examine the responsiveness of their pre-tax income to changes in interest rates, exchange rates, and commodity prices.[9] Beginning with base case assumptions about the financial prices, the firm obtains a forecast for revenues, costs, and the resulting pre-tax income. Then, it considers alternative values for an interest rate or an exchange rate or a commodity price and obtains a new forecast for revenues, costs, and pre-tax income. By observing how the firm's projected sales, costs and income move in response to changes in these financial prices, management is able to trace out a risk profile similar to that in Figure 1.

In making such an estimation, two inherent problems confront the analyst: (1) this approach requires substantial data and (2) it relies on the ability of the researcher to make explicit, accurate forecasts of sales and costs under alternative scenarios for the financial prices. For both these reasons, such an approach is generally feasible only for analysts within a specific firm.

Stock Measures. Given the data requirements noted above, analysts outside the firm generally rely on market valuations, the most widely used of which is the current market value of the equity. Using a technique much like the one used to estimate a firm's "beta," an outside observer could measure the historical sensitivity of the company's equity value to changes in interest rates, foreign exchange rates, and commodity prices.

For example, suppose we wished to determine the sensitivity of a company's value to the following financial prices:

- the one-year T-bill interest rate;
- the Deutsche Mark / Dollar exchange rate;
- the Pound Sterling / Dollar exchange rate;
- the Yen / Dollar exchange rate; and
- the price of oil.

7. Note the contrast with the gap approach, which relates changes in the interest rate to changes in net interest income.

8. The calculations in Table 1 are based on the use of MacCauley's duration. If we continue to apply MacCauley's duration (D), this equation is only an approximation. To be exact, modified duration should be used. For a development of this relation, see George G. Kaufman, G.O. Bierwag, and Alden Toevs, eds. *Innovations in Bond Portfolio Management: Duration Analysis and Immunization* (Greenwich, Conn.: JAI Press, 1983).

9. See for instance, Paul Dickens, cited in note 2.

TABLE 2
MEASUREMENTS OF EXPOSURES TO INTEREST RATE, FOREIGN EXCHANGE RATES, AND OIL PRICES

Percentage Change In	Chase Manhattan		Caterpillar		Exxon	
	Parameter Estimate	T Value	Parameter Estimate	T Value	Parameter Estimate	T Value
Price of 1-Year T-Bill	2.598*	1.56	−3.221**	1.76	1.354	1.24
Price of DM	−0.276	0.95	0.344	1.07	−0.066	0.35
Price of Sterling	0.281	1.16	−0.010	0.38	0.237*	1.50
Price of Yen	−0.241	0.96	0.045	0.16	−0.278**	1.69
Price of WTI Crude	0.065	1.21	−0.045	0.77	0.082***	2.33

* Significant at 90% single tailed
** Significant at 90%
*** Significant at 95%

We could estimate this relation by performing a simple linear regression as follows:[10]

$$R_t = a + b_1\left(\frac{\Delta P_{TB}}{P_{TB}}\right)_t + b_2\left(\frac{\Delta P_{DM}}{P_{DM}}\right)_t + b_3\left(\frac{\Delta P_{£}}{P_{£}}\right)_t + b_4\left(\frac{\Delta P_{Y}}{P_{Y}}\right)_t + b_5\left(\frac{\Delta P_{OIL}}{P_{OIL}}\right)_t$$

where R is the rate of return on the firm's equity; $\Delta P_{TB} / P_{TB}$ is the percentage change in the price of a one-year T-bill; $\Delta P_{DM}/P_{DM}$, $\Delta P_{£}/P_{£}$, and $\Delta P_{y}/P_{y}$ are the percentage changes in the dollar prices of the three foreign currencies; and $\Delta P_{OIL} / P_{OIL}$ is the percentage change in the price of crude oil. The estimate of b_1 provides a measure of the sensitivity of the value of the firm to changes in the one-year T-bill rate; b_2, b_3, and b_4 estimate its sensitivity to the exchange rates; and b_5 estimates its sensitivity to the oil price.[11]

To illustrate the kind of results this technique would yield, we present three examples: a bank, Chase Manhattan, an industrial, Caterpillar, and an oil company, Exxon. For the period January 6, 1984 to December 2, 1988 we calculated weekly (Friday close to Friday close) share returns and the corresponding weekly percentage changes in the price of a one-year T-bill rate, the dollar prices of a Deutsche Mark, a Pound Sterling, and a Yen, and the price of West Texas Intermediate crude. Using these data, we estimated our regression equation. The results of these estimations are displayed in Table 2.

Given the tendency of banks to accept short-dated deposits to fund longer-dated assets (loans), it is not surprising that our estimates for Chase Manhattan indicate an inverse exposure to interest rates. Although only marginally significant, the positive coefficient indicates that an increase in the one-year T-bill

TABLE 2.A

Bank	Estimated Sensitivity	T-Value
Bank of America	3.2	1.5
Bankers Trust	2.2	1.4
Chase	2.6	1.6
First Chicago	3.0	1.6
Manufacturers Hanover	3.2	1.9

10. In effect, this equation represents a variance decomposition. While it is a multifactor model, it is not related in any important way to the APT approach suggested by Ross and Roll. Instead, it is probably more accurate to view the approach we suggest as an extension of the market model. In its more complete form, as described in Chapter 2 of our book *Managing Financial Risk*, the regression equation would include the rate of return to the market ("beta") as well as the percentage changes in the financial prices, and would thus look as follows:

$$R_t = a + \beta R_{m,t} + b_1PC(P_{TB}) + b_2PC(P_{DM}) + b_3PC(P_{£}) + b_4PC(P_{Y}) + b_5PC(P_{OIL})$$

This more complete model is based on a number of earlier studies: French/Ruback/Schwert (1983) ("Effects of Nominal Contracting on Stock Returns," *Journal of Political Economy*, Vol. 91 No. 1) on the impact of unexpected inflation on share returns, Flannery/James (1984) ("The Effect of Interest Rate Changes on Common Stock Returns of Financial Institutions," *Journal of Finance* Vol. 39 No. 4) and Scott/Peterson (1986) ("Interest Rate Risk and Equity Values of Hedged and Unhedged Financial Intermediaries," *Journal of Financing Research* Vol. 9 No. 6) on the impact of interest rate changes on share prices for financial firms, and Sweeney/Warga (1986) ("The Pricing of Interest Rate Risk: Evidence from the Stock Market," *Journal of Finance* Vol. 41 No. 2) on the impact of interest rate risk on share prices for nonfinancial firms. This model does exhibit the problems of measuring the reaction of firm value to changes in exchange rates, which are described by Donald Lessard in "Finance and Global Competition: Exploiting Financial Scope and Coping with Volatile Exchange Rates," *Midland Corporate Finance Journal* (Fall 1986).

For expositional purposes, we use in this paper the shorter form of the equation. This abbreviated model is acceptable empirically given the small correlations which exist between the percentage changes in the financial prices and the market return.

11. These coefficients actually measure elasticities. Further, had we used the percentage change in the quantity, (1 + one-year T-bill rate), instead of the percentage change in the price of the one-year T-bill, the coefficient b_1 could be interpreted as a "duration" measure.

TABLE 2.B

	1984	1985	1986	1987	1988
Parameter Estimate for Percentage Change in Price of Yen	1.72	0.15	0.33	−1.08	−0.85
T-Value	1.59	0.31	0.65	1.08	1.53

TABLE 2.C

	1984	1985	1986	1987	1988
Parameter Estimate for Percentage Change in Price of Oil	0.80	0.15	0.09	0.05	−0.01
T-Value	3.94	0.85	2.79	0.37	0.17

rate (or a decrease in the price of the T-bill) is expected to lead to a decrease in the bank's value.

Additional information can be obtained by comparing the coefficient estimates among firms in the same industry. For example, we can compare the estimated sensitivity of Chase's value to the one-year T-bill rate to the sensitivities of other banks as shown in Table 2.A.

In contrast to the bank's inverse exposure, Caterpillar appears to have a positive exposure to the one-year T-bill rate. That is, the negative regression coefficient indicates that increases in the one-year T-bill rate (or decreases in the price of the T-bill) lead to increases in the value of the firm.

Even more surprising, though, given much that has been written about Caterpillar's exposure to foreign currency changes, is the lack of any significant exposure to the yen. This result is more understandable if we break up this 5-year span into shorter intervals and look at Caterpillar's sensitivity to the price of the yen on a year-by-year basis. (See Table 2.B.) The data reflect the fact that, as Caterpillar has moved its production facilities, the firm has changed from being positively exposed to the yen (such that an increase in the value of the dollar would harm Caterpillar) to being negatively exposed to the yen (an increase in the value of the dollar now helps Caterpillar).

Unlike the other two firms, the estimate for Exxon's exposure to interest rates is not statistically significant (not, at least, to the one-year T-bill rate). Exxon does exhibit the expected positive exposure to the price of oil. But our estimates also reflect the now common view, reported in the financial press and elsewhere, that Exxon's exposure to the price of oil has been declining over time—both in size and consistency (as measured by statistical significance). (See Table 2.C.) Given its international production and distribution, as well as its international portfolio of assets, Exxon also exhibits marginally significant exposures to foreign exchange rates. Our estimates suggest Exxon benefits from an increase in the value of the pound but is harmed by an increase in the value of the yen.

Measuring Corporate Exposure: Summing Up

The purpose of this first section, then, has been to outline a statistical technique (similar to that used to calculate a firm's "beta") that can be used to provide management with an estimate of the sensitivity of firm value to changes in a variety of financial variables. Such measures can be further refined by using information from other sources. For example, the same regression technique can be used, only substituting changes in the firm's periodic earnings and cash flows for the changes in stock prices in our model. There are, however, two principal advantages of our procedure over the use of such accounting numbers: (1) market reactions are likely to capture the entire capitalized value of changes in firm value in response to financial price changes; and (2) regression analysis using stock prices, besides being much faster and cheaper, can be done using publicly available information.

THE TOOLS FOR MANAGING FINANCIAL RISK: A BUILDING BLOCK APPROACH[12]

If it turns out that a firm is subject to significant financial price risk, management may choose to hedge that risk.[13] One way of doing so is by using an "on-balance-sheet" transaction. For example, a company could manage a foreign exchange exposure resulting from overseas competition by borrowing in the competitor's currency or by moving production abroad. But such on-balance sheet methods can be costly and, as firms like Caterpillar have discovered, inflexible.[14]

Alternatively, financial risks can be managed with the use of off-balance-sheet instruments. The four fundamental off-balance-sheet instruments are forwards, futures, swaps, and options.

When we first began to attempt to understand these financial instruments, we were confronted by what seemed an insurmountable barrier to entry. The participants in the various markets all seemed to possess a highly specialized expertise that was applicable in only one market to the exclusion of all others (and the associated trade publications served only to tighten the veil of mystery that "experts" have always used to deny entry to novices). Options were discussed as if they were completely unrelated to forwards or futures, which in turn seemed to have nothing to do with the latest innovation, swaps. Adding to the complexities of the individual markets was the welter of jargon that seems to have grown up around each, thus further obscuring any common ground that might exist. (Words such as "ticks," "collars," "strike prices," and "straddles" suddenly had acquired a remarkable currency.) In short, we seemed to find ourselves looking up into a Wall Street Tower of Babel, with each group of market specialists speaking in different languages.

But, after now having observed these instruments over the past several years, we have been struck by how little one has to dig before superficial differences give way to fundamental unity. And, in marked contrast to the specialized view of most Wall Street practitioners, we take a more "generalist" approach—one that treats forwards, futures, swaps, and options not as four unique instruments and markets, but rather as four interrelated instruments for dealing with a single problem: managing financial risk. In fact, we have come up with a little analogy that captures the spirit of our conclusion, one which goes as follows: The four basic off-balance-sheet instruments—forwards, futures, swaps, and options—are much like those plastic building blocks children snap together. You can either build the instruments from one another, or you can combine the instruments into larger creations that appear (but appearances deceive) altogether "new."

Forward Contracts

Of the four instruments, the forward contract is the oldest and, perhaps for this reason, the most straightforward. A forward contract obligates its owner to buy a specified asset on a specified date at a price (known as the "exercise price") specified at the origination of the contract. If, at maturity, the actual price is higher than the exercise price, the contract owner makes a profit equal to the difference; if the price is lower, he suffers a loss.

In Figure 2, the payoff from buying a forward contract is illustrated with a hypothetical risk profile. If the actual price at contract maturity is higher than the expected price, the inherent risk results in a decline in the value of the firm; but this decline is offset by the profit on the forward contract. Hence, for the risk profile illustrated, the forward contract provides an effective hedge. (If the risk profile were positively instead of negatively sloped, the risk would be managed by selling instead of buying a forward contract.)

Besides its payoff profile, a forward contract has two other features that should be noted. First, the default (or credit) risk of the contract is two-sided. The contract owner either receives or makes a payment, depending on the price movement of the underlying

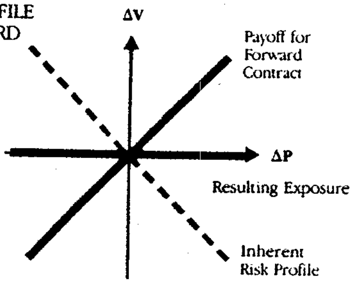
12 This section of the article is adapted from Charles W. Smithson, "A LEGO Approach to Financial Engineering: An Introduction to Forwards, Futures, Swaps, and Options," *Midland Corporate Finance Journal* 4 (Winter 1987).

13 In this paper we do not address the question of why public corporations hedge. For a discussion of the corporate decision whether or not to hedge financial price exposures, see Alan Shapiro and Sheridan Titman, "An Integrated Approach to Corporate Risk Management," *Midland Corporate Finance Journal* 3 (Summer 1985) For other useful theoretical discussions of the corporate hedging decision, see David Mayers and Clifford Smith, "On the Corporate Demand for Insurance," *Journal of Business* 55 (April 1982) (a less technical version of which was published as "The Corporate Insurance Decision," *Chase Financial Quarterly* (Vol. 1 No. 3) Spring 1982); Rene Stulz, "Optimal Hedging Policies," *Journal of Financial and Quantitative Analysis* 19 (June 1984); Clifford Smith and Rene Stulz, "The Determinants of Firms' Hedging Policies," *Journal of Financial* and *Quantitative Analysis* 20 (December 1985)

For some empirical tests of the above theoretical work, see David Mayers and Clifford Smith, "On the Corporate Demand for Insurance: Some Empirical Evidence," working paper, 1988; and Deana Nance, Clifford Smith, and Charles Smithson, "The Determinants of Off-Balance-Sheet Hedging: An Empirical Analysis," working paper 1988.

14. See "Caterpillar's Triple Whammy," *Fortune*, October 27, 1986.

FIGURE 2
PAYOFF PROFILE FOR FORWARD CONTACT



asset. Second, the value of the forward contract is conveyed only at the contract's maturity; no payment is made either at origination or during the term of the contract.

Futures Contracts

The basic form of the futures contract is identical to that of the forward contract; a futures contract also obligates its owner to purchase a specified asset at a specified exercise price on the contract maturity date. Thus, the payoff profile for the purchaser of a forward contract as presented in Figure 2 could also serve to illustrate the payoff to the holder of a futures contract.

But, unlike the case of forwards, credit or default risk can be virtually eliminated in a futures market. Futures markets use two devices to manage default risk. First, instead of conveying the value of a contract through a single payment at maturity, any change in the value of a futures contract is conveyed at the end of the day in which it is realized. Look again at Figure 2. Suppose that, on the day after origination, the financial price rises and, consequently, the financial instrument has a positive value. In the case of a forward contract, this value change would not be received until contract maturity. With a futures contract, this change in value is received at the end of the day. In the language of the futures markets, the futures contract is "marked-to-market" and "cash settled" daily.

Because the performance period of a futures contract is reduced by marking to market, the risk of default declines accordingly. Indeed, because the value of the futures contract is paid or received at the end of each day, Fischer Black likened a futures contract to "a series of forward contracts [in which] each day, yesterday's contract is settled and today's contract is written."[15] That is, a futures contract is like a sequence of forwards in which the "forward" contract written on day 0 is settled on day 1 and is replaced, in effect, with a new "forward" contract reflecting the new day 1 expectations. This new contract is then itself settled on day 2 and replaced, and so on until the day the contract ends.

The second feature of futures contracts which reduces default risk is the requirement that all market participants—sellers and buyers alike—post a performance bond called the "margin."[16] If my futures contract increases in value during the trading day, this gain is added to my margin account at the day's end. Conversely, if my contract has lost value, this loss is deducted from my margin account. And, if my margin account balance falls below some agreed-upon minimum, I am required to post additional bond; that is, my margin account must be replenished or my position will be closed out.[17] Because the position will be closed before the margin account is depleted, performance risk is eliminated.[18]

Note that the exchange itself has not been proposed as a device to reduce default risk. Daily settlement and the requirement of a bond reduce default risk, but the existence of an exchange (or clearinghouse) merely serves to transform risk. More specifically, the exchange deals with the two-sided risk inherent in forwards and futures by serving as the counterparty to all transactions. If I wish to buy or sell a futures contract, I buy from or sell to the exchange. Hence, I need only evaluate the credit risk of the exchange, not of some specific counterparty.

The primary economic function of the exchange is to reduce the costs of transacting in futures

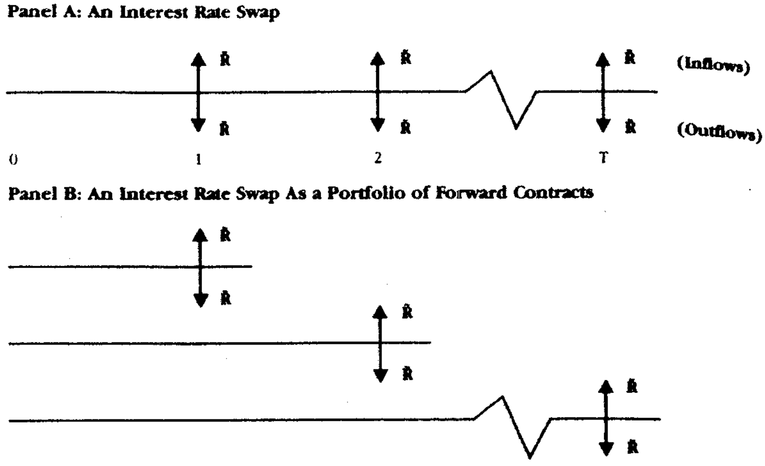
15. See Fischer Black "The Pricing to Commodity Contracts," *Journal of Financial Economics* 3 (1976), 167-179.

16. Keep in mind that if you buy a futures contract, you are taking a long position in the underlying asset. Conversely, selling a futures contract is equivalent to taking a short position.

17. When the contract is originated on the U.S. exchanges, an "initial margin" is required. Subsequently, the margin account balance must remain above the "maintenance margin." If the margin account balance falls below the maintenance level, the balance must be restored to the initial level.

18. Note that this discussion has ignored daily limits. If there are daily limits on the movement of futures prices, large changes in expectations about the underlying asset can effectively close the market. (The market opens, immediately moves the limit, and then is effectively closed until the next day.) Hence, there could exist an instance in which the broker desires to close out a customer's position but is not able to immediately because the market is experiencing limit moves. In such a case, the statement that performance risk is "eliminated" is too strong.

FIGURE 3



contracts. The anonymous trades made possible by the exchange, together with the homogeneous nature of the futures contracts—standardized assets, exercise dates (four per year), and contract sizes—enables the futures markets to become relatively liquid. However, as was made clear by recent experience of the London Metal Exchange, the existence of the exchange does not in and of itself eliminate the possibility of default.[19]

In sum, a futures contract is much like a portfolio of forward contracts. At the close of business of each day, in effect, the existing forward-like contract is settled and a new one is written.[20] This daily settlement feature combined with the margin requirement allows futures contracts to eliminate the credit risk inherent in forwards.

Swap Contracts[21]

A swap contract is in essence nothing more complicated than a series of forward contracts strung together. As implied by its name, a swap contract obligates two parties to exchange, or "swap," some specified cash flows at specified intervals. The most common form is the interest rate swap, in which the cash flows are determined by two different interest rates.

Panel A of Figure 3 illustrates an interest rate swap from the perspective of a party who is paying out a series of cash flows determined by a fixed interest rate ($\bar{R}$) in return for a series of cash flows determined by a floating interest rate ($\tilde{R}$).[22]

Panel B of Figure 3 serves to illustrate that this swap contract can be decomposed into a portfolio of

19. In November of 1985, the "tin cartel" defaulted on contracts for tin delivery on the London Metal Exchange, thereby making the exchange liable for the loss. A description of this situation is contained in "Tin Crisis in London Roils Metal Exchange," *The Wall Street Journal*, November 13, 1985.

From the point of view of the market, the exchange does not reduce default risk. The expected default rate is not affected by the existence of the exchange. However, the existence of the exchange can alter the default risk faced by an individual market participant. If I buy a futures contract for a specific individual, the default risk I face is determined by the default rate of that specific counterparty. If I instead buy the same futures contract through an exchange, my default risk depends on the default rate of not just my counterparty, but on the default rate of he entire market. Moreover, to the extent that the exchange is capitalized by equity from its members, the default risk I perceive is further reduced because I have a claim not against some specific counterparty, but rather against the exchange. Therefore, when I trade through the exchange, I am in a sense purchasing an insurance policy from the exchange.

20. A futures contract is like a portfolio of forward contracts; however, a futures contract and a portfolio of forward contracts become identical only if interest rates are "deterministic"—that is, known with certainty in advance. See Robert A. Jarrow and George S. Oldfield, "Forward Contracts and Futures Contracts," *Journal of Financial Economics* 9 (1981), 373-382; and John A. Cox, Jonathan E. Ingersoll, and Stephen A. Ross, "The Relation between Forward Prices and Futures Prices," *Journal of Financial Economics* 9 (1981), 321-346.

21. This section is based on Clifford W. Smith, Charles W. Smithson, and Lee M. Wakeman, "The Evolving Market for Swaps," *Midland Corporate Finance Journal* Winter (1986), 20-32.

22. Specifically, the interest rate swap cash flows are determined as follows. The two parties agree to some notional principal, P. (The principal is notional in the sense that it is only used to determine the magnitude of cash flows, is is not paid or received by either party.) At each settlement date, 1, 2,..., T the party illustrated makes a payment $\bar{R} = \bar{r}P$, where $\bar{r}$ is the T-period fixed rate which existed at origination. At each settlement, the party illustrated receives $\tilde{R} = \tilde{r}P$, where $\tilde{r}$ is the floating rate for that period (e.g., at settlement date 2, the interest rate used is the one-period rate in effect at period 1).

forward contracts. At each settlement date, the party to this swap contract has an implicit forward contract on interest rates: the party illustrated is obligated to sell a fixed-rate cash flow for an amount specified at the origination of the contract. In this sense, a swap contract is also like a portfolio of forward contracts.

In terms of our earlier discussion, this means that the solid line in Figure 2 could also represent the payoff from a swap contract. Specifically, the solid line in Figure 3 would be consistent with a swap contract in which the party illustrated receives cash flows determined by one price (say, the U.S. Treasury bond rate) and makes payments determined by another price (say, LIBOR). Thus, in terms of their ability to manage risk, forwards, futures, and swaps all function in the same way.

But identical payoff *patterns* notwithstanding, the instruments all differ with respect to default risk. As we saw, the performance period of a forward is equal to its maturity; and because no performance bond is required, a forward contract is a pure credit instrument. Futures both reduce the performance period (to one day) and require a bond, thereby eliminating credit risk. Swap contracts use only one of these mechanisms to reduce credit risk; they reduce the performance period.[23] This point becomes evident in Figure 3. Although the maturity of the contract is T periods, the performance period is generally not T periods long but is instead a single period. Thus, given a swap and a forward contract of roughly the same maturity, the swap is likely to impose far less credit risk on the counterparties to the contract than the forward.

At each settlement date throughout a swap contract, the changes in value are transferred between the counterparties. To illustrate this in terms of Figure 3, suppose that interest rates rise on the day after origination. The value of the swap contract illustrated has risen. This value change will be conveyed to the contract owner not at maturity (as would be the case with a forward contract) nor at the end of that day (as would be the case with a futures contract). Instead, at the first settlement date, part of the value change is conveyed in the form of the "difference check" paid by one party to the other. To repeat, then, the performance period is less than that of a forward, but not as short as that of a futures contract.[24] (Keep in mind that we are comparing instruments with the same maturities.)

Let us reinforce the two major points made thus far. First, a swap contract, like a futures contract, is like a portfolio of forward contracts. Therefore, the payoff profiles for each of these three instruments are identical. Second, the primary difference among forwards, futures, and swaps is the amount of default risk they impose on counterparties to the contract. Forwards and futures represent the extremes, and swaps are the intermediate case.

Option Contracts

As we have seen, the owner of a forward, futures, or swap contract has an *obligation* to perform. In contrast, an option gives its owner a *right*, not an obligation. An option giving its owner the right to buy an asset at a pre-determined price—a call option—is provided in Panel A of Figure 4. The owner of the contract has the right to purchase the asset at a specified future date at a price agreed-upon today. Thus, if the price rises, the value of the option also goes up. But because the option contract owner is not obligated to purchase the asset if the price moves against him, the value of the option remains unchanged (at zero) if the price declines.[25]

The payoff profile for the party who sold the call option (also known as the call "writer") is shown in Panel B. In contrast to the buyer of the option, the seller of the call option has the *obligation* to perform. For example, if the owner of the option elects to exercise his option to buy the asset, the seller of the option is obligated to sell the asset.

Besides the option to buy an asset, there is also the option to sell an asset at a specified price, known as a "put" option. The payoff to the buyer of a put is illustrated in Panel C of Figure 4, and the payoff to the seller of the put is shown in Panel D.

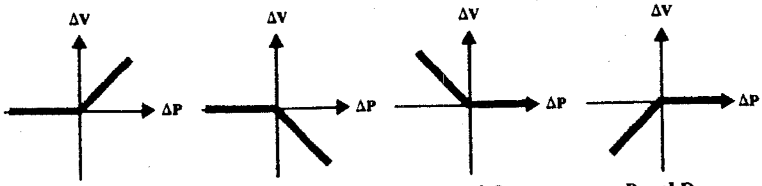
Pricing Options: Up to this point, we have considered only the payoffs to the option contracts. We have side-stepped the thorniest issue—the valuation of option contracts.

23 There are instances in a which bond has been posted in the form of collateral As should be evident, in this case the swap becomes very like a futures contract

24 Unlike futures, for which all of any change in contract value is paid/received at the daily settlements, swap contracts convey only part of the total value change at the periodic settlements.

25. For continuity, we continue to use the $\Delta V, \Delta P$ convention in figures. To compare these figures with those found in most texts, treat ΔV as deviations from zero ($\Delta V = V - 0$) and remember that P measures deviations from expected price ($\Delta P = P - P_e$).

FIGURE 4
PAYOFF PROFILES OF
PUTS AND CALLS



The breakthrough in option pricing theory came with the work of Fischer Black and Myron Scholes in 1973.[26] Conveniently for our purposes, Black and Scholes took what might be described as a "building block" approach to the valuation of options. Look again at the call option illustrated in Figure 4. For increases in the financial price, the payoff profile for the option is that of a forward contract. For decreases in the price, the value of the option is constant—like that of a "riskless" security such as a Treasury bill.

The work of Black and Scholes demonstrated that a call option could be replicated by a continuously adjusting ("dynamic") portfolio of two securities: (1) forward contracts on the underlying asset and (2) riskless securities. As the financial price rises, the "call option equivalent" portfolio contains an increasing proportion of forward contracts on the asset. Conversely, the replicating portfolio contains a decreasing proportion of forwards as the price of the asset falls.

Because this replicating portfolio is effectively a synthetic call option, arbitrage activity should ensure that its value closely approximates the market price of exchange-traded call options. In this sense, the value of a call option, and thus the premium that would be charged its buyer, is determined by the value of its option equivalent portfolio.

Panel A of Figures 5 illustrates the payoff profile for a call option which includes the premium. This figure (and all of the option figures thus far) illustrates an "at-the-money" option—that is, an option for which the exercise price is the prevailing expected price. As Panels A and B of Figure 5 illustrate, an at-the-money option is paid for by sacrificing a significant amount of the firm's potential gains. However, the price of a call option falls as the exercise price increases relative to the prevailing price of the asset. This means that if an option buyer is willing to accept larger potential losses in return for paying a lower option premium, he would then consider using an "out-of-the-money" option.

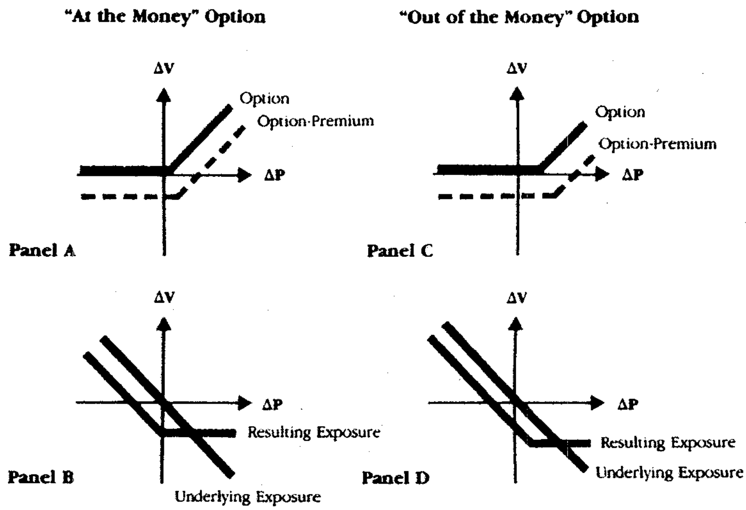
An out-of-the-money call option is illustrated in Panel C of Figure 5. As shown in Panel D, the out-of-the-money option provides less downside protection, but the option premium is significantly less. The lesson to be learned here is that the option buyer can alter his payoff profile simply by changing the exercise price.

For our purposes, however, the most important feature of options is that they are not as different from other financial instruments as they might first seem. Options do have a payoff profile that differs significantly from that of forward contracts (or futures or swaps). But, option payoff profiles can be duplicated by a combination of forwards and risk-free securities. Thus, we find that options have more in common with the other instruments than was first apparent. Futures and swaps, as we saw earlier, are in essence nothing more than portfolios of forward contracts; and options, as we have just seen, are very much akin to portfolios of forward contracts and risk-free securities.

This point is reinforced if we consider ways that options can be combined. Consider a portfolio constructed by buying a call and selling a put with the

26. See Fischer Black and Myron Scholes, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy* 1973. For a less technical discussion of the model, see "The Black-Scholes Option Pricing Model for Alternative Underlying Instruments," *Financial Analysts Journal*, November-December, 1984, 23-30.

FIGURE 5



same exercise price. As the left side of Figure 6 illustrates, the resulting portfolio (long a call, short a put) has a payoff profile equivalent to that of buying a forward contract on the asset. Similarly, the right side of Figure 6 illustrates that a portfolio made up of selling a call and buying a put (short a call, long a put) is equivalent to selling a forward contract.

The relationship illustrated in Figure 6 is known more formally as "put-call parity." The special import of this relationship, at least in this context, is the "building block construction" it makes possible: two options can be "snapped together" to yield the payoff profile for a forward contract, which is identical to the payoff profile for futures and swaps.

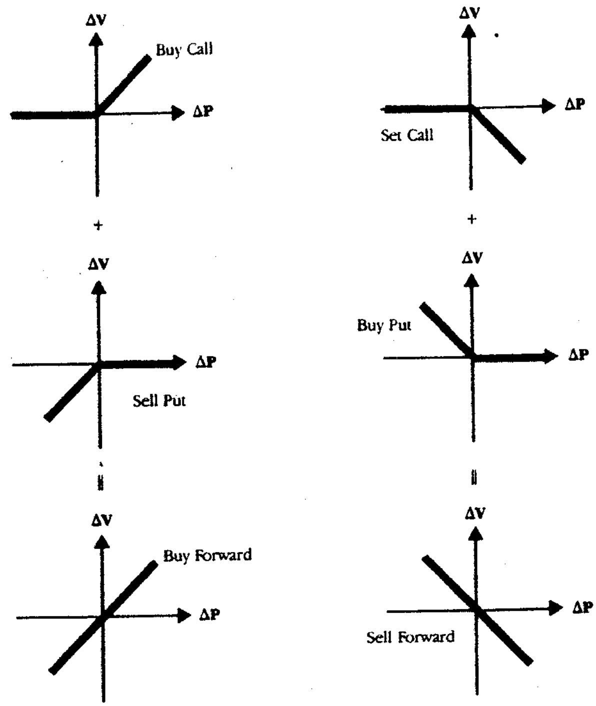
At the beginning of this section, then, it seemed that options would be very different from forwards, futures, and swaps—and in some ways they are. But we discovered two building block relations between options and the other three instruments: (1) options can be replicated by "snapping together" a forward, futures, or swap contract together with a position in risk-free securities; and (2) calls and puts can be combined to become forwards.

The Financial Building Blocks

Forwards, futures, swaps, and options—they all look so different from one another. And if you read the trade publications or talk to the specialists that transact in the four markets, the apparent differences among the instruments are likely to seem even more pronounced.

But it turns out that forwards, futures, swaps, and options are not each unique constructions, but rather more like those plastic building blocks that children combine to make complex structures. To understand the off-balance-sheet instruments, you don't need a lot of market-specific knowledge. All you need to know is how the instruments can be linked to one another. As we have seen, (1) futures can be built by "snapping together" a package of forwards; (2) swaps can also be built by putting together a package of forwards; (3) synthetic options can be constructed by combining a forward with a riskless security; and (4) options can be combined to produce forward contracts—or, conversely, forwards can be pulled apart to replicate a package of options.

FIGURE 6



Having shown you all the building blocks and how they fit together in simple constructions, we now want to demonstrate how they can be used to create more complicated, customized financial instruments that in turn can be used to manage financial risks.

ASSEMBLING THE BUILDING BLOCKS

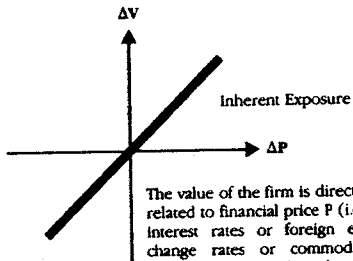
Using The Building Blocks to Manage an Exposure

Consider a company whose market value is directly related to unexpected changes in some financial price, P. The risk profile of this company is illustrated in Figure 7. How could we use the financial building blocks to modify this inherent exposure?

The simplest solution is to use a forward, a futures, or a swap to neutralize this exposure. This is shown in Panel A of Figure 8.

But, the use of a forward, a futures, or a swap

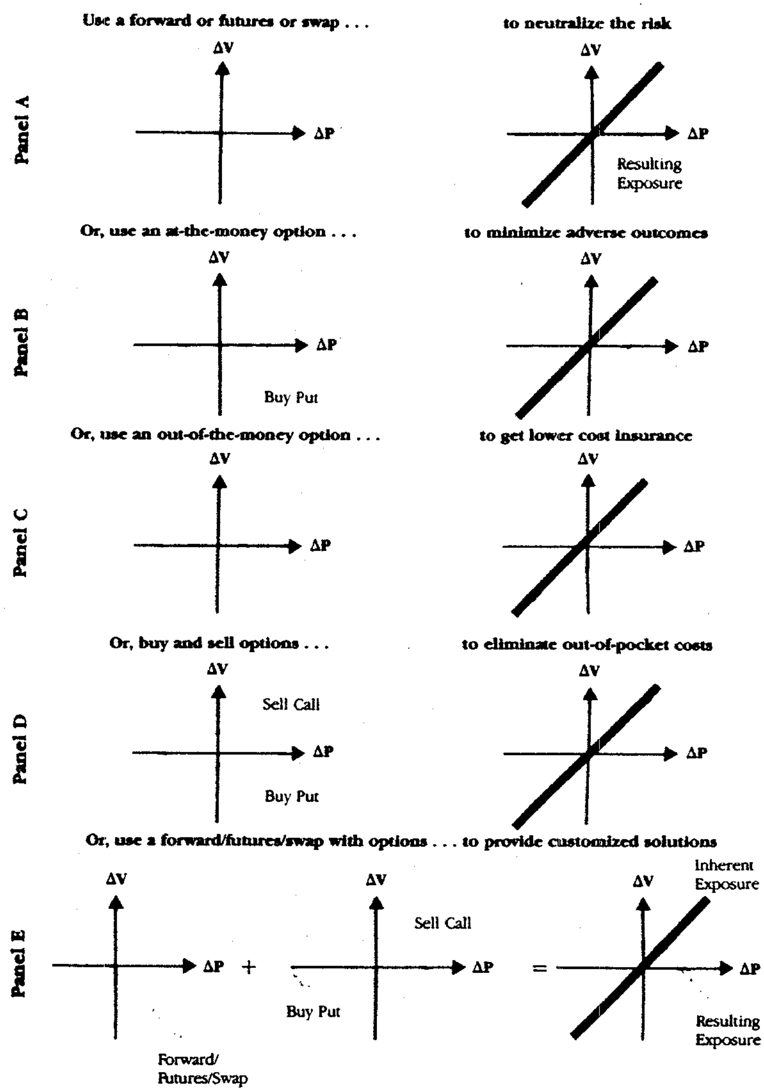
FIGURE 7



The value of the firm is directly related to financial price P (i.e., interest rates or foreign exchange rates or commodity prices). If P rises, the value of the firm rises.

eliminates possible losses by giving up the possibility of profiting from favorable outcomes. The company might want to minimize the effect of unfavorable outcomes while still allowing the possibility of gaining from favorable ones. This can be accom-

FIGURE 8


Panel A
Use a forward or futures or swap . . .
ΔV
ΔP
to neutralize the risk
ΔV
ΔP
Resulting
Exposure
Panel B
Or, use an at-the-money option . . .
ΔV
ΔP
Buy Put
to minimize adverse outcomes
ΔV
ΔP
Panel C
Or, use an out-of-the-money option . . .
ΔV
ΔP
to get lower cost insurance
ΔV
ΔP
Panel D
Or, buy and sell options . . .
ΔV
Sell Call
ΔP
Buy Put
to eliminate out-of-pocket costs
ΔV
ΔP
Panel E
Or, use a forward/futures/swap with options . . . to provide customized solutions
ΔV
ΔP
+
Forward/
Futures/Swap
ΔV
Sell Call
ΔP
Buy Put
=
ΔV
Inherent
Exposure
ΔP
Resulting
Exposure

plished using options. The payoff profile of an at-the-money option (including the premium paid to buy the option) is shown on the left side of Panel B. Snapping this building block onto the inherent exposure profile gives the resulting exposure illustrated on the right side of panel B.

A common complaint about options—especially at-the-money options—is that they are "too expensive." To reduce the option premium, you can think about using an out-of-the-money option. As Panel C of Figure 8 illustrates, the firm has thereby given up some protection from adverse outcomes in return for paying a lower premium.

But, with an out-of-the-money option, some premium expense remains. Panel D illustrates how the out-of-pocket expense can be *eliminated*. The firm can sell a call option with an exercise price chosen so as to generate premium income equal to the premium due on the put option it wishes to purchase. In building block parlance, we snap the "buy-a-put" option onto the inherent risk profile to reduce downside outcomes; and we snap on the "sell-a-call" option to fund this insurance by giving up some of the favorable outcomes.

Panel E reminds us that forwards, futures, and swaps can be used in combination with options. Suppose the treasurer of the company we have been considering comes to you with the following request:

I think that this financial price, P, is going to fall dramatically. And, while I know enough about financial markets to know that P could actually rise a little, I am sure it will not rise by much. I want some kind of financial solution that will let me benefit when my predictions come to pass. But I don't want to pay any out-of-pocket premiums. Instead, I want this financial engineering product to pay me a premium.

If you look at the firm's inherent risk profile in Figure 7, this seems like a big request. The firm's inherent position is such that it would lose rather than gain from big decreases in P.

The resulting exposure profile shown on the right side of Panel E is the one the firm wants: it benefits from large decreases in P, is protected against small increases in P (though not against large increases) and receives a premium for the instrument.

How was this new profile achieved? As illustrated on the left side of Panel E, we first snapped a forward/futures/swap position onto the original risk profile to neutralize the firm's inherent exposure. We then sold a call option and bought a put option with exercise prices set such that the income from selling the call exceeded the premium required to buy the put.

No high level math was required. Indeed, we did this bit of financial engineering simply by looking through the box of financial building blocks until we found those that snapped together to give us the profile we wanted.

Using the Building Blocks to Redesign Financial Instruments

Now that you understand how forwards, futures, swaps, and options are all fundamentally related, it is a relatively short step to thinking about how the instruments can be combined with each other to give one financial instrument the characteristics of another. Rather than talk about this in the abstract, let's look at some examples of how this has been done in the marketplace.

Combining Forwards with Swaps: Suppose a firm's value is currently unaffected by interest rate movements. But, at a known date in the future, it expects to become exposed to interest rates: if rates rise, the value of the firm will decrease.[27] To manage this exposure, the firm could use a forward, futures, or swap commencing at that future date. Such a product is known as a *forward* or *delayed start* swap. The payoff from a forward swap is illustrated in Panel C of Figure 9, where the party illustrated pays a fixed rate and receives floating starting in period 5.

Although this instrument is in effect a forward contract on a swap, it also, not surprisingly, can be constructed as a package of swaps. As Figure 9 illustrates, a forward swap is equivalent to a package of two swaps:

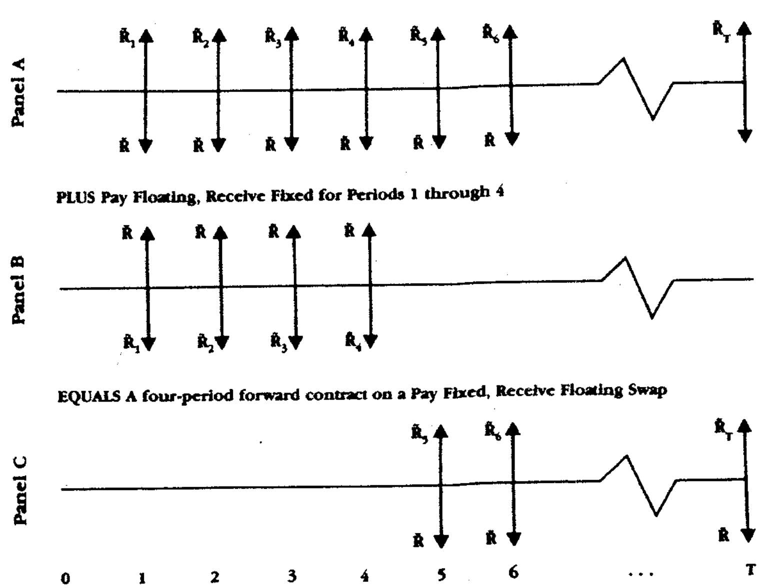
Swap 1—From period 1 to period T, the party pays fixed and receives floating.

Swap 2—From period 1 to period 4, the party pays floating and receives fixed.

Forwards with Option-like Characteristics: The addition of option-like characteristics to forward

27. For example, the firm may know that, in one year, it will require funds which will be borrowed at a floating rate, thereby giving the firm the inverse exposure to interest rates. Or, the firm may be adding a new product line, the demand for which is extremely sensitive to interest rate movements—as rates rise, the demand for the product decreases and cash flows to the firm decrease.

FIGURE 9 **Pay Fixed, Receive Floating for Period 1 through T**



contracts first appeared in the foreign exchange markets. To see how this was done, let's trace the evolution of these contracts.

Begin with a standard forward contract on foreign exchange. Panel A of Figure 10 illustrates a conventional forward contract on sterling with the forward sterling exchange rate (the "contract rate") set at $1.50 per pound sterling. If, at maturity, the spot price of sterling exceeds $1.50, the owner of this contract makes a profit (equal to the spot rate minus $1.50). Conversely, if at maturity the spot price of sterling is less than $1.50, the owner of this contract suffers a loss. The owner of the forward contract, however, might instead want a contract that allows him to profit if the price of sterling rises, but limits his losses if the price of sterling falls.[28] Such a contract would be a call option on sterling. Illustrated in Panel B of Figure 10 is a call option on sterling with an exercise price of $1.50. In this illustration we have assumed an option premium of 5 cents (per pound sterling).

The payoff profile illustrated in Panel B of Figure 10 could also be achieved by altering the terms of the standard forward contract as follows:

1. Change the contract price so that the exercise price of the forward contract is no longer $1.50 but is instead $1.55. The owner of the forward contract agrees to purchase sterling at contract maturity at a price of $1.55 per unit; and

2. Permit the owner of the contract to break (i.e. "unwind") the agreement at a sterling price of $1.50.

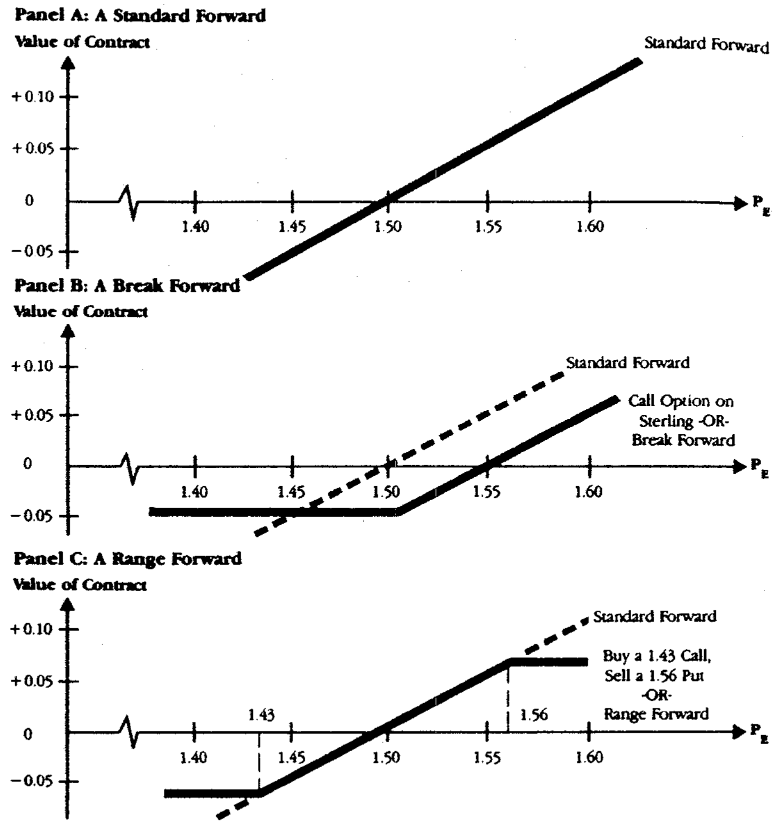
This altered forward contract is referred to as a *break forward* contract.[29] In this break forward construction, the premium is effectively being paid by the owner of the break forward contract in the form of the above market contract exchange rate.

From our discussion of options, we also know that a call can be paid for with the proceeds from selling a put. The payoff profile for such a situation is

28. This discussion is adapted from Warren Edwardes and Edmond Levy, "Break Forwards: A Synthetic Option Hedging Instrument," *Midland Corporate Finance Journal* 5 (Summer 1987) 59-67.

29. According to Sam Srinivasulu in "Second-Generation Forwards: A Comparative Analysis," Business International Money Report, September 21, 1987, break forward is the name given to this construction by Midland Bank. It goes under other names: Boston Option (Bank of Boston), FOX – Forward with Optional Exit (Hambros Bank), and Cancelable Forward (Goldman Sachs)

FIGURE 10



illustrated in Panel C of Figure 10. In this illustration, we have assumed that the proceeds of a put option on sterling with an exercise price of $1.56 would carry the same premium as a call option on sterling with an exercise price of $1.43.[30]

A payoff profile identical to this option payoff profile could also be generated, however, simply by changing the terms of a standard forward contract to the following:

- at maturity, the buyer of the forward contract agrees to purchase sterling at a price of $1.50 per pound sterling;
- the buyer of the forward contract has the right to break the contract at a price of $1.43 per pound sterling; and
- the seller of the forward contract has the right to break the contract at a price of $1.56 per pound sterling.

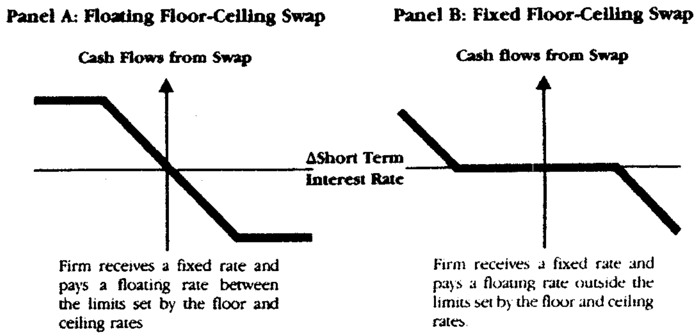
Such a forward contract is referred to as a *range forward*.[31]

Swaps with Option-like Characteristics: Given that swaps can be viewed as packages of forward contracts, it should not be surprising that swaps can also be constructed to have option-like

30. These numbers are only for purposes of illustration. To determine the exercise prices at which the values of the puts and calls are equal, one would have to use an option pricing model.

31. As Srinivasulu, cited note 29, pointed out, this construction also appears under a number of names: range forward (Salomon Brothers), collar (Midland Montagu), flexible forward (Manufacturers Hanover), cylinder option (Citicorp), option fence (Bank of America) and mini-max (Goldman Sachs).

FIGURE 11
PAY-OFF PROFILE FOR FLOOR-CEILING SWAPS



characteristics like those illustrated for forwards. For example, suppose that a firm with a floating-rate liability wanted to limit its outflows should interest rates rise substantially; at the same time, it was willing to give up some potential gains should there instead be a dramatic decline in short-term rates. To achieve this end, the firm could modify the interest rate swap contract as follows:

As long as the interest rate neither rises by more than 200 basis points nor falls more than 100 basis points, the firm pays a floating rate and receives a fixed rate. But, if the interest is more than 200 basis points above or 100 basis points below the current rate, the firm receives and pays a fixed rate.

The resulting payoff profile for this floating floor ceiling swap is illustrated in Panel A of Figure 11.

Conversely, the interest rate swap contract could have been modified as follows:

As long as the interest rate is within 200 basis points of the current rate, the firm neither makes nor receives a payment; but if the interest rate rises or falls by more than 200 basis points, the firm pays a floating rate and receives a fixed rate.

The payoff profile for the resulting fixed floor-ceiling swap is illustrated in Panel B of Figure 11.

Redesigned Options: To "redesign" an option, what is normally done is to put two or more options together to change the payoff profile. Examples abound in the world of the option trader. Some of the more colorfully-named combinations are *straddles*, *strangles*, and *butterflies*.[32]

To see how and why these kinds of creations evolve, let's look at a hypothetical situation. Suppose a firm was confronted with the inherent exposure illustrated in Panel A of Figure 12. Suppose further that the firm wanted to establish a floor on losses caused by changes in a financial price.

As you already know, this could be done by purchasing an out-of-the-money call option on the financial price. A potential problem with this solution, as we have seen, is the premium the firm has to pay. Is there a way the premium can be eliminated?

We have already seen that buying an out-of-the-money call can be financed by selling an out-of-the-money put. However, suppose that this out-of-the-money call is financed by selling a put with precisely the same exercise price—in which case, the put would be in-the-money. As illustrated in Panel B of Figure 12, the proceeds from selling the in-the-money put would exceed the cost of the out-of-the-money call. Therefore, to finance one out-of-the-money call, one would need sell only a fraction of one in-the-money put.

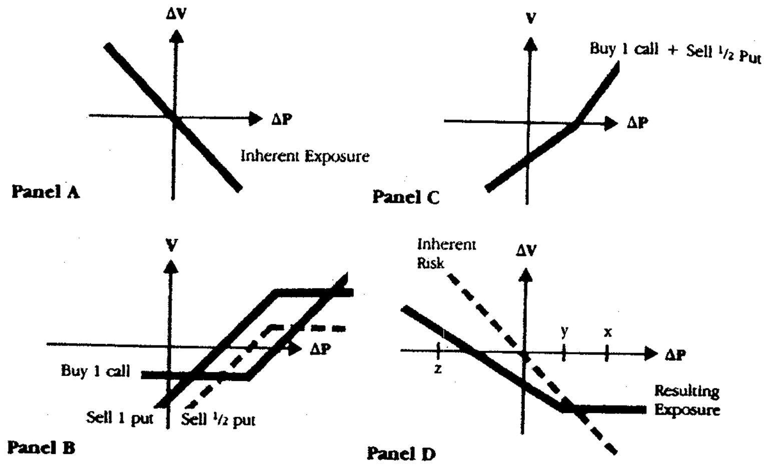
In Panel B, we have assumed that the put value is twice the call value; so, to finance one call, you need sell only 1/2 put. Panel C simply combines the payoff profiles for selling 1/2 put and buying one call with an exercise price of X. Finally, Panel D of Figure 12 combines the option combination in Panel C with the inherent risk profile in Panel A.

Note what has happened. The firm has obtained the floor it wanted, but there is no up-front premium.

32. For a discussion of traditional option strategies like straddles, strangles, and butterflies, see for instance chapter 7 of Richard M. Bookstaber, *Option Pricing and Strategies in Investing* (Addison-Wesley, 1981).

INVOLVE NOTHING MORE THAN PUTTING THE BUILDING BLOCKS
TOGETHER IN A NEW WAY.

FIGURE 12



At the price at which the option is exercised, the value of the firm with the floor is the same as it would have been without the floor. The floor is paid for not with a fixed premium, but with a share of the firm's gains above the floor. If the financial price rises by X, the value of the firm falls to the floor and no premium is paid. If, however, the financial price rises by less, say Y, the value of the firm is higher and the firm pays a positive premium for the floor. And, if the financial price falls, say, by Z, the price it pays for the floor rises.

What we have here is a situation where the provider of the floor is paid with a share of potential gains, thereby leading to the name of this option combination—a *participation*. This construction has been most widely used in the foreign exchange market where they are referred to as *participating forwards*.[33]

Options on Other Financial Instruments

Options on futures contracts on bonds have been actively traded on the Chicago Board of Trade since 1982. The valuation of an option on a futures is a relatively straightforward extension of the traditional option pricing models.[34] Despite the close relation between futures and forwards and futures and swaps, the options on forwards (*options on forward rate agreements*) and options on swaps (*swaptions*) are much more recent.

More complicated analytically is the valuation of an option on an option, also known as a *compound option*.[35] Despite their complexity and resistance to valuation formulae, some options on options have begun to be traded. These include options on foreign exchange options and, most notably, options on interest rate options (caps), referred to in the trade as *captions*.

Using the Building Blocks to Design "New" Products

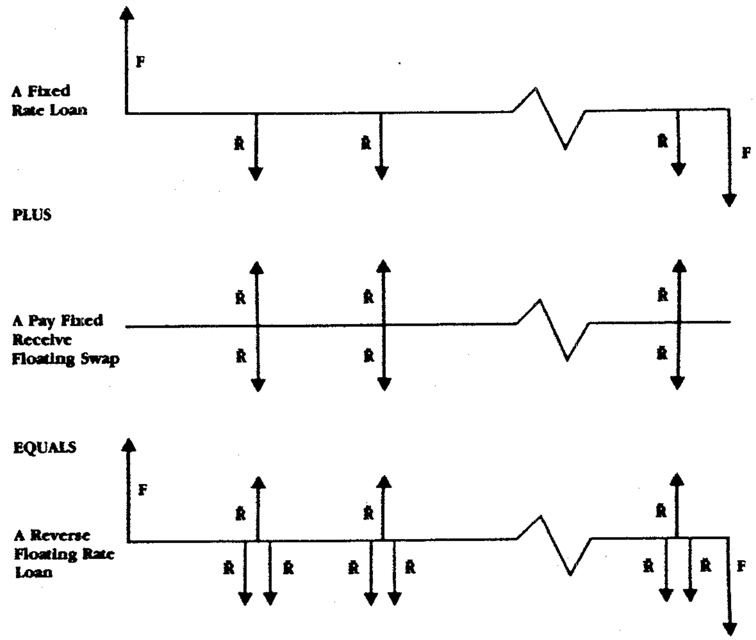
It's rare that a day goes by in the financial markets without hearing of at least one "new" or "hybrid" product. But, as you should have come to expect from us by now, our position with respect to "financial engineering" is that there is little new under the sun. The "new" products typically involve nothing more than putting the building blocks together in a new way.

33 For more on this construction, see Srinivalsulu cited in note 29 and 31.

34 Options on futures were originally discussed by Fischer Black in "The Pricing of Commodity Options," *Journal of Financial Economics* 3 (January-March 1976). A concise discussion of the modifications required in the Black-Scholes formula is contained in James F. Meisner and John W. Labuszewski, "Modifying the Black-Scholes Option Pricing Model for Alternative Underlying Instruments," *Financial Analysts Journal* November/December 1984.

35. For a discussion of the problem of valuing compound options, see John C. Cox and Mark Rubinstein, *Options Markets* (Prentice-Hall, 1985) 412-415.

FIGURE 13
USING A SWAP TO CREATE A REVERSE FLOATING RATE LOAN



Reverse Floaters: One example of a hybrid security is provided in Figure 13. If we combine the issuance of a conventional fixed rate loan and an interest rate swap where the issuing party pays fixed and receives floating, the result is a reverse floating-rate loan. The net coupon payments on the hybrid loan are equal to twice the fixed rate ($\bar{r}$) minus the floating rate ($\tilde{r}$) times the principal (P), or

$$\textbf{Net Coupon} = (2\bar{r} - \tilde{r})P = 2\bar{R} - \tilde{R}$$

If the floating rate ($\tilde{r}$) rises, the net coupon payment falls.

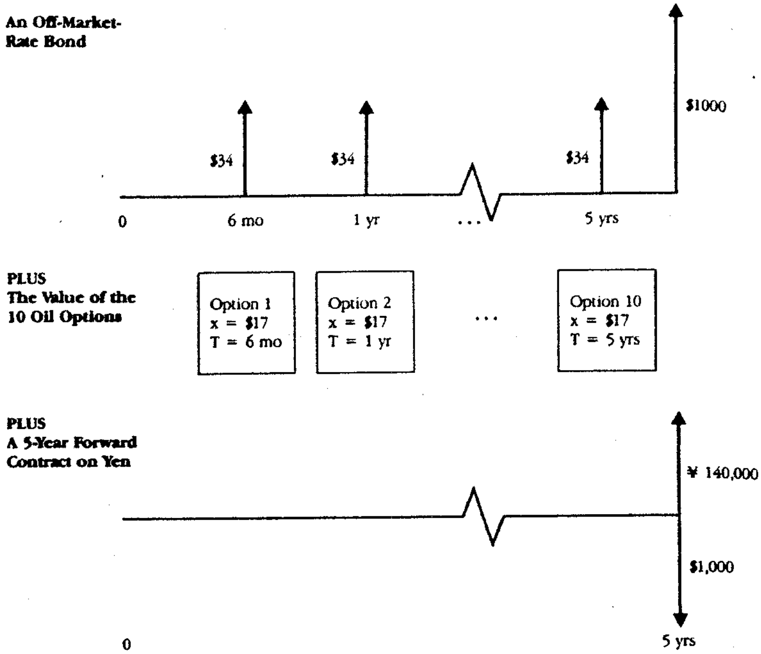
Bonds with Embedded Options: Another form of hybrid securities has evolved from bonds with warrants. Bonds with warrants on the issuer's shares have become common. Bond issues have also recently appeared that feature warrants that can be exercised into foreign exchange and gold.

And, in 1986, Standard Oil issued a bond with an oil warrant. These notes stipulated that the principal payment at maturity would be a function of oil prices at maturity. As specified in the Prospectus, the holders of the 1990 notes will receive, in addition to a guaranteed minimum principal amount, "the excess...of the Crude Oil Price...over $25 multiplied by 170 barrels of Light Sweet Crude Oil." What this means is that the note has an embedded four-year option on 170 barrels of crude oil. If, at maturity, the value of Light Sweet Oklahoma Crude Oil exceeds $25, the holder of the note will receive (Oil Price − $25) x 170 plus the guaranteed minimum principal amount. If the value of Light Sweet Oklahoma Crude is less than $25 at maturity, the option expires worthless.[36]

The building block process has also been extended to changes in the timing of the options

36 Note that this issue did have a cap on the crude oil price at $40. Hence, the bondholder actually holds two options positions: long a call option at $25 per barrel and short a call option at $40 per barrel.

FIGURE 14



embedded in the bond. For a traditional bond with an attached warrant, there is only one option exerciseable at one point in time. More recent bonds have involved packages of options which can be exercised at different points in time.

The first time we saw this extension was in Forest Oil Corporation's proposed *Natural Gas Interest Indexed Debentures*. As set forth in the issue's red herring prospectus of July 1988, Forest Oil proposed to pay a stipulated base rate plus four basis points for each $0.01 by which the average gas spot price exceeds $1.76 per MMBTU (million British Thermal Units). In effect, then, this proposed 12-year "hybrid" debenture is a package consisting of one standard bond plus 24 options on the price of natural gas with maturities ranging from 6 months to 12 years.[37]

And, if we want to get a little fancier, we can consider the possibility of an *Oil Interest-Indexed, Dual-Currency Bond*.[38] Assume that the maturity of this issue is 5 years, with the semi-annual coupon payments indexed to the price of crude oil and the final principal repayment indexed to the value of yen. More specifically, assume that, for each $1000 of principal, the bondholder receives the following: (1) the greater of $34 or the value of two barrels of Sweet Light Crude Oil at each coupon date; and (2) 140,000 yen at maturity.

How would we value such a complicated package? The answer, again, is by breaking it down into the building blocks. As shown in Figure 14, this oil-indexed, dual currency bond consists of three basic components: (1) a straight bond paying $34 semi-annually; (2) 10 call options on the price of oil with an exercise price of $17 per barrel ($34/2) maturing sequentially every six months over a five-year period; and (3) a five-year forward contract on yen with an exercise price of 140 yen/dollar. As it turns out, then, this complicated-looking bond is nothing more than a combination of a standard bond, a series of options, and a forward contract.

37. As reported in the Wall Street Journal on September 21, 1988, Forest Oil withdrew its Natural Gas Indexed Bond in favor of a straight issue. However, in November of 1988, Magma Copper did issue senior subordinated notes on which the coupon payments were linked to the price of copper in much the same way as Forest's coupons would been linked to the price of natural gas.

38. Unlike the other structures discussed, this one has not yet been issued.

CONCLUDING REMARKS

The world is more volatile today than it was two decades ago. Today's corporate risk manager must deal with the potential impact on the firm of significant month-to-month (and sometimes day-to-day) changes in exchange rates, interest rates, and commodity prices. Volatility alone could put a well-run firm out of business, so financial price risk deserves careful attention. As this summary has demonstrated, there now exist techniques and tools for accomplishing this task.

This article makes three major points:

First, there are simple techniques that allow management (and outsiders as well) to identify and measure a firm's exposures. Besides managing "one-off" exposures (such as interest rate exposures from floating-rate borrowings or foreign exchange transaction and translation exposures), many firms are now recognizing their economic exposures. To measure such economic exposures, we have introduced the concept of the *risk profile*. Using this concept, we have proposed simple methods for quantifying the extent of an individual firm's exposures to interest rates, foreign exchange rates, and commodity prices. In the case of a financial firm's exposure to interest rate risk, the techniques of "gap" and "duration" analysis can be applied directly. For the more general case, we demonstrate how simple regression analysis (the same technique used in calculating a firm's "beta") can be used to measure a variety of exposures.

Second, the tools for managing financial risk are more simple than they appear. These financial instruments can be viewed as building blocks. The basic component is a forward contract. Both futures and swaps are like bundles of forward contracts; forwards, in fact, can be combined to yield futures and swaps. The primary differences between these two instruments are the way they deal with default risk and the degree of customization available.

Even options, moreover, can be related to forward contracts. An option on a given asset can be created by combining a position in a forward contract on the same asset with a riskless security; in short, forwards and T-bills can be combined to produce options.[39] Finally, options can be combined to create forward positions; for example, buying a call and shorting a put produces the same position as buying a forward contract.

Third, once you understand the four basic building blocks, it is a straightforward step to designing a customized strategy for managing your firm's exposure. Once the exposure is identified, it can be managed in a number of ways:

- by using one of the financial instruments—for example, by using an interest rate swap to hedge a building products firm's exposure to rising interest rates;
- by using combinations of the financial instruments—for example, buying a call and selling a put to minimize the out-of-pocket costs of the hedge; or
- by combining financial instruments with a debt instrument to create a hybrid security—for example, issuing an oil-indexed bond to hedge a firm's exposure to oil prices.

Our final point in all of this is very simple. Managing financial price risk with "financial engineering" sounds like something you need a degree from Caltech or M.I.T. to do. Designing effective solutions with the financial building blocks is easy.

39. This is most often referred to as a synthetic option or as dynamic option replication.