# Risk Management & Derivatives

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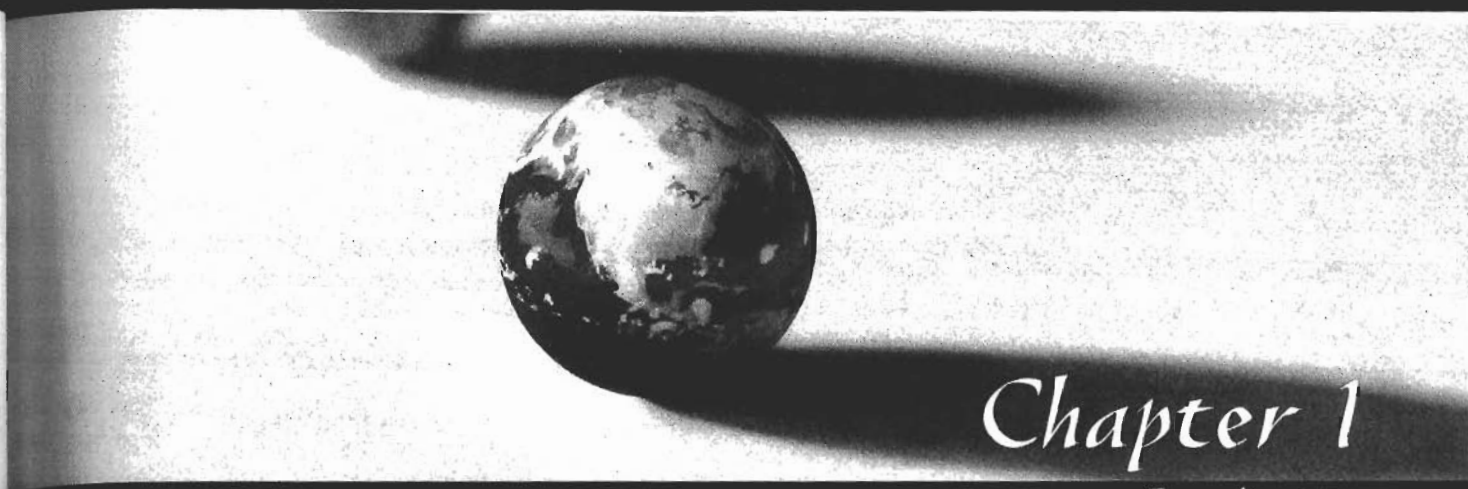


# Chapter 1

## Introduction

Throughout history, the weather has determined the prospects of nations, businesses, and individuals. Nations have gone to war to take over land with a better climate. Businesses have faltered because the goods they produced were not in demand as a result of unexpected weather developments. People have starved when their crops failed because of poor weather.

Avoiding losses due to weather has been the dream of visionaries and the stuff of science fiction novels—until it became the work of financial engineers, who devise new financial instruments and strategies to enable firms and individuals to pursue their financial goals. Businesses and individuals can now use financial products to protect themselves against the financial consequences of bad weather. Financial instruments that help us deal with weather risks are just one example of the remarkable role of derivatives in managing risks.

In chemistry, a derivative is a "substance related structurally to another substance and theoretically derivable from it . . . a substance that can be made from another substance." Derivatives in finance work on the same principle. They are financial instruments whose promised payoffs are derived from the value of something else, generally called the underlying. The underlying is often a financial asset, but it does not have to be. In a weather derivative, the underlying can be the temperature at a specific location, such as Kennedy Airport in New York. More precisely, a derivative is a financial instrument with promised payoffs derived from the value of one or several contractually specified underlyings.

**A call option** on IBM gives the right to buy a fixed number of shares of IBM at a contractually specified price, the **exercise price**. A call option on IBM is a derivative with IBM common stock as its underlying. The payoff of the call is the difference between the value of the shares received and the payment made. This payoff has to be positive since the option holder does not have to buy the shares if it is not advantageous for him or her to do so.

The underlyings that determine the promised payoffs of a derivative can be anything that the contracting parties find useful. They might include stock prices, bond prices, interest rates, gold prices, egg prices, exchange rates, number of

houses destroyed by hurricanes, and the number of personal bankruptcies within a calendar year in the United States. A derivative can have a payoff that depends on many underlyings. For example, Microsoft uses derivatives that have payoffs derived from the price of several foreign currencies.

Management can create value for shareholders by using derivatives to manage risk. Consider Garman Inc., which exports software to Europe. Its only foreign currency payment in the fiscal year is a payment of €100 million in six months. A euro is expected to be worth $1 in six months. Suppose that when the receivable is paid, one euro is worth only $0.90. If Garman has done nothing to manage its foreign exchange risk, it has an unexpected cash flow shortfall of $10 million. This loss forces it to cut its R&D budget, which damages its competitive position.

Garman Inc. can eliminate the risk of a large cash flow shortfall by buying a **put option** on the euro. A put option gives its holder the right to sell a fixed quantity of the underlying at the contractually agreed upon price, the exercise price. If Garman Inc. buys a put option on €100 million with a maturity of six months and an exercise price of $1 per euro, it can sell its euros for $1 per euro if the euro is less than $1 when it receives its payment. It has to pay a premium for this insurance, but with this insurance it will not have to cut its R&D program if the euro depreciates sharply. If Garman does not use derivatives to limit the risk of a cash flow shortfall, its equity value is reduced because investors impound in the stock price the possibility that the company will have to cut back its R&D following a depreciation of the euro.

Countless firms use derivatives to reduce risks associated with foreign currency transactions. Though researchers have only recently started to investigate the impact of the use of derivatives on firms' equity, one recent study shows that multinational firms that use currency derivatives have a higher value than multinational firms that do not. The research show that, for the same assets, the total value of the debt and of the equity of large multinational firms that use foreign currency derivatives is 3.6 to 5.3 percent higher than for comparable firms that do not use them.

Derivatives are useful not only to manage risks that corporations have already taken, but they also enable firms to change what they do, to think of new profitable strategies. For example, a new type of weather derivative enabled Bombardier of Canada, a manufacturer of snowmobiles, to adopt a marketing strategy that would have been too risky otherwise. In the winter of 1998, Bombardier offered buyers of snowmobiles in the U.S. Midwest a rebate of $1,000 if snowfall did not exceed a pre-set amount. It eliminated the risk of the rebate using a weather derivative based on a snowfall index. The derivative paid an amount based on the total number of millimeters of snow below an agreed upon amount. Bombardier estimates that the program generated an increase in sales of 38 percent, which is more than it paid for the derivative.

Though derivatives can be used to increase shareholder wealth substantially, they can seriously damage a firm when used without appropriate training and care. The fall of Barings in 1995 following losses in excess of $1 billion from derivatives trades showed that a long and distinguished history provides no insur-

ance against a derivatives disaster. Barings was London's oldest merchant bank, had negotiated the purchase of Louisiana by the United States from Napoleon in 1803, and counted the Queen of England among its clients. Firms from Procter & Gamble to Metallgesellschaft have incurred large losses, received bad publicity, and fired executives because of derivatives trades. Orange County filed for bankruptcy because of losses in a county fund partly caused by derivatives. The manager of the fund was quoted after the debacle saying "I wish I had known more about these complex instruments."

If a firm uses derivatives when its managers are not equipped to do so, shareholders suffer. Derivatives are like jets. They make it possible to reach a destination faster, but untrained or poorly trained users can crash. There are books that teach how to build jets and books that teach how to fly jets. This book is about flying, not building. It is about using derivatives, not about the technical issues surrounding the pricing of derivatives. This book teaches how to successfully manage risks with derivatives.

Managing risk with derivatives often involves using derivatives to hedge. A **hedge** is a financial position put on to reduce the impact of a risk one is exposed to; to hedge means putting on a hedge. However, as we will see, sometimes it makes sense for a firm to choose derivatives positions that increase risks the firm is exposed to.

The remainder of this chapter explains first what is behind the growth of derivatives instruments that made this book possible. We then describe some basic ideas concerning derivatives as risk management tools and discuss how to use derivatives correctly. To illustrate some of the risk management issues managers face, we provide examples from Merck and Microsoft. Finally, we outline the book.

## 1.1. The growth of derivatives markets

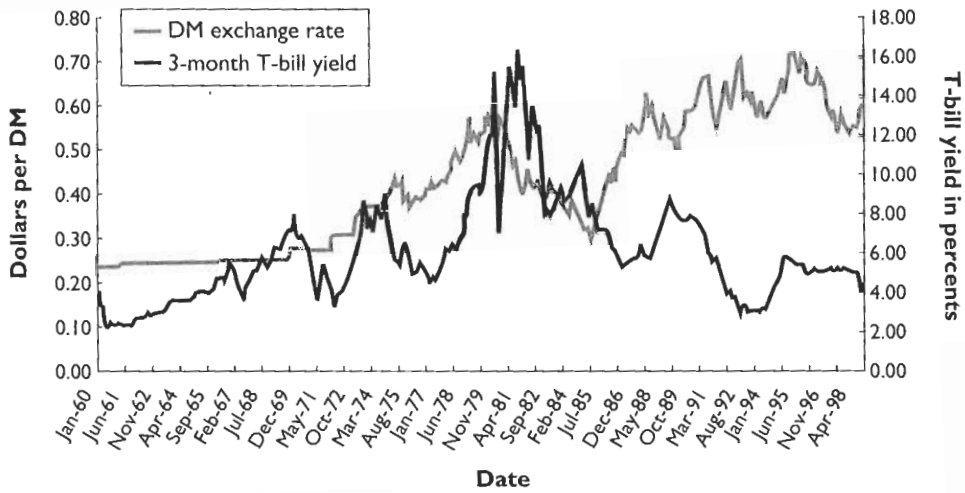
Some of the earliest derivatives markets are the market for tulip options in 17th century Holland and the futures market for rice in Japan in the same century. Derivatives have been traded for centuries, but until recently derivatives markets were small and of limited economic importance. In the 1970s, changes in economic conditions and crucial developments in the theory of the pricing of derivatives created the conditions for the spectacular growth in derivatives markets we have experienced since then. According to the publication *The Economist*, use of derivatives increased by a factor of twelve in the 1990s alone.[1]

In developed economies, interest rate volatility increased sharply in the 1970s, making it imperative for firms and investors to find ways to hedge interest rate risks. Until the early 1970s, most currencies had fixed exchange rates. As fixed exchange rate arrangements collapsed, the volatility of exchange rates became an important source of risk for corporations. Figure 1.1 shows these changes in the

1 See "School Brief: Future Perfect," *The Economist*, November 27, 1999.

*Figure 1.1*

**DM exchange rate and T-bill yield from January 1960 to December 1998**




**Source:** Datastream.

behavior of exchange rates and interest rates for the dollar price of the German mark and for the 3-month T-bill yield. Other changes in the economic environment, such as the deregulation of several industries, the spectacular growth in international trade, and the globalization of financial markets, increased the demand for financial products to manage risk further.

Development of a formula by two financial economists in Boston in the early 1970s revolutionized the field of options and changed markets for derivatives forever. One of these financial economists, Fischer Black, was a consultant. The other, Myron Scholes, was an assistant professor at the Massachusetts Institute of Technology who had just earned a Ph.D. in finance from the University of Chicago. At that time, available options were almost exclusively stock options. The two men realized that by investing in a portfolio of stocks and bonds and actively managing that portfolio, one could obtain the same outcome as if one had invested in stock options. With this insight and the critical help of another assistant professor at the Massachusetts Institute of Technology, Robert Merton, they derived a formula that became instantly famous: the Black-Scholes formula for the pricing of options.

Almost immediately, the approach used by Black and Scholes to price options was found useful not only to price stock options, but also to price, evaluate the risk of, and hedge derivatives that have little resemblance to traditional options. Financial engineers could invent new instruments and find their value with the pricing method of the Black-Scholes formula.

In a risky world, there are many opportunities for trades whereby one party shifts risks to another party through derivatives. These trades must be mutually beneficial or they would not take place. Until the 1970s, the trading of risks mostly took the form of option and forward transactions. In a **forward contract,**

one party agrees to buy the underlying from another party at maturity of the contract and pay for it then a price agreed upon when the contract is originated. In our example of Garman, Garman can buy a put to sell euros at a fixed price by paying a premium, but it can also enter a forward contract without paying anything now to sell €100 million at an agreed upon price, say $1 per euro, in six months. With the forward contract, Garman has to deliver €100 million to its counterparty in six months and receives $100 million for doing so regardless of the price of the euro.

Eventually, financial futures contracts were introduced, which are contracts akin to forward contracts but traded on exchanges. Then, the swaps market took off. **Swaps** are exchanges of cash flows derived from underlyings. In the simplest swap, one party promises to pay cash flows corresponding to the interest payments of fixed rate debt on a given amount to a party that promises to pay cash flows corresponding to the payments of floating-rate debt on the same principal amount. The **notional amount** of a derivative is the quantity of the underlying used to determine the payoff of the derivative. The amount on which the interest is computed in an interest-rate swap, the notional amount of the swap, is not exchanged.

The best indicator of the growth and significance of the derivatives industry is that observers debate whether derivatives markets are larger and more influential than the markets for stocks and bonds. The Bank for International Settlements (BIS) measures the size of the markets using the notional amount of derivatives. This measure is interesting because it proxies for the value of the underlyings against which claims are traded in the derivatives markets. According to the BIS as of the end of December 2001, the total notional amount of derivatives was $111 trillion. At that time, world GDP was $31.3 trillion and the capitalization of the stock markets of the industrialized countries was $21.2 trillion.

Another approach could be used to compute the size of the derivatives market. Instead of using notional amounts, we could measure the value of the derivatives outstanding. In the Garman example, the notional amount of the put is €100 million, but the value of the put is the price that it would fetch if sold. If the price of the euro is much higher than $1, the right to sell €100 million for $100 million would have little value. The BIS estimate of the total value of derivatives for the end of December 2001 is $3.8 trillion. The daily turnover of exchange rate and interest rate derivatives trading over the counter in April 2001 was estimated by the BIS at a total notional amount of $575 billion, while the daily turnover of exchange-traded exchange rate and interest rate derivatives measured using the notional amount was $2.2 trillion.

In today's derivatives markets, any type of financial payoff one can think of can be obtained at a price. If a corporation would benefit receiving a large payment in the unlikely event that Citibank and Chase default in the same month, it can go to an investment bank and arrange to enter the appropriate derivatives contract. If another corporation wants to receive a payment that is a function of the square of the yen/dollar exchange rate if the volatility of the S&P 500 exceeds 35 percent during a month, it can do so.

When anything is possible, but one does not have the required knowledge or experience, it is easy to make mistakes. It is of crucial importance to know how

to use derivatives the right way to manage risk. This requires an understanding of how risk affects shareholder wealth, an understanding that was not available in 1970. The developments in finance that offer a framework for understanding how to use derivatives to maximize shareholder wealth date from the 1980s and the 1990s.

## 1.2. Some basic ideas concerning derivatives as risk management tools

Options and forward contracts are often called **plain vanilla derivatives** because they are the simplest derivatives. They differ in two critical ways. First, a call option contract gives a right to buy (or sell if it is a put option contract) the underlying at a fixed price whereas a forward contract gives an obligation to buy the underlying at a fixed price for the buyer and to sell at a fixed price for the seller. Second, an exchange of money takes place when one enters an option contract but no money changes hands when a forward contract is originated. These differences between options and forwards have important implications for how corporations and investors should use derivatives.

### 1.2.1. Options

The best-known options are on common stock. Whoever sells an option at inception of the contract is called the **option writer**. The call option writer promises to deliver shares for the exercise price, and the put option writer promises to pay the exercise price for shares. An option has value for its holder since the holder can never lose money by exercising the option but can make large gains. Consequently, an option writer is only willing to write an option if he is adequately compensated. The price at which an option can be bought is called the **option premium**.

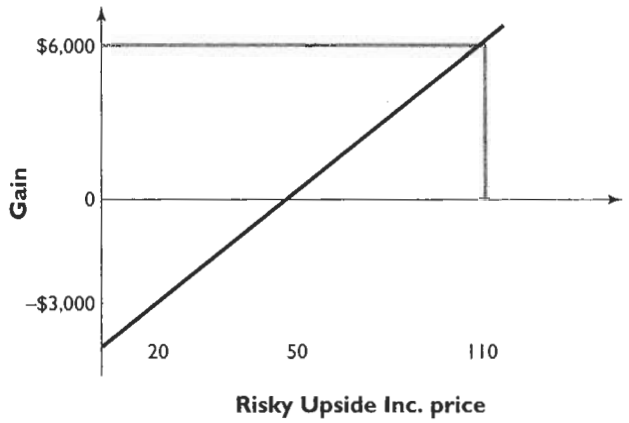
Option contracts are for 100 shares but they are quoted per share. Consider a call option on Risky Upside Inc. The stock price is $50, and the price of a call option that gives the right to buy the stock at $50 per share, the exercise price, is $10. This call option gives the right to its holder to buy 100 shares of Risky Upside Inc. stock at $50 per share. The option premium per share is $10.

Options differ as to when the right they represent can be exercised. For **European options**, the right can be exercised only at maturity. For **American options**, the right can be exercised at maturity and before. Suppose investor Rubinstein believes that Risky Upside Inc. is likely to improve on its price of $50 per share over the next ten months. Rubinstein could buy 100 shares of Risky Upside Inc. for $5,000, but if the price drops sharply over the next ten months, she would lose much of her investment. If she wants to benefit from increases in the price of Risky Upside Inc. but limit her potential loss, she can buy a call option on Risky Upside Inc. stock for $1,000 (100 times $10 per share). The greatest loss she would then incur over the holding period is the price paid to acquire the option.

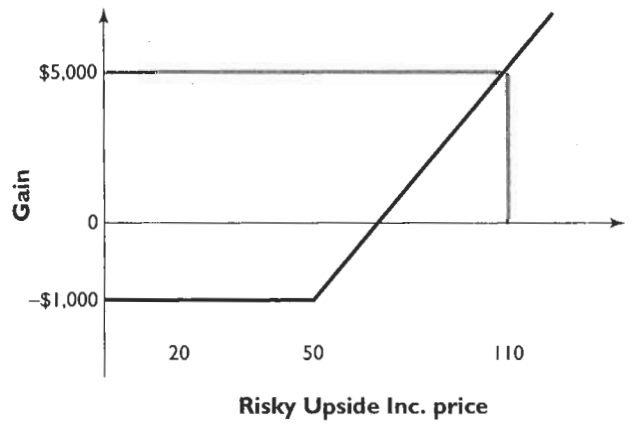
Figure 1.2 compares the gain of holding 100 Risky Upside Inc. shares for ten months and of buying a European call option on 100 shares with ten months to maturity. If after ten months the share price falls to $20, the investor who bought 100 shares loses $3,000, but the investor who bought the call option loses only the $1,000 premium paid for the call. If the share price increases to $110, the in-

**Gains and losses from buying shares and a call option on Risky Upside Inc.** *Figure 1.2*

Panel A. Gain from buying shares of Risky Upside Inc. at $50 per share.




Panel B. Gain from buying a call option on shares of Risky Upside Inc. with exercise price of $50 for a premium of $10 per share.




vestor who bought shares gains $6,000, but the investor who bought the option gains only $5,000—the gain of $6,000 from exercising the option minus the $1,000 premium paid.

In Figure 1.2, it would cost $1,000 to buy a call on 100 shares, but $5,000 to buy 100 shares. Options enable their holders to lever their resources. The same is true for many derivatives strategies. This implicit leverage can make the value of derivatives positions extremely volatile. By investing $1,000 of her own money to buy the call option, Rubinstein receives $100 more for each dollar the stock price exceeds the exercise price when she receives the payoff from the option. Consequently, Rubinstein gains from stock price increases as if she had invested in 100 shares even though she invests an amount of money only equal to the value of 20 shares. Without call options and only $1,000 to invest, Rubinstein would have to borrow $4,000 to be able to buy 100 shares if she wants to earn

$100 more per dollar the stock price exceeds the exercise price. The gain made upon exercising the option is therefore similar to the gain from a levered position in the underlying—a position consisting of purchasing shares with one's own money and some borrowed money.

By buying the call, Rubinstein earns much more if the stock price exceeds $50 at maturity and loses much more if it is below $50 than if she invests $1,000 in shares and does not borrow. If the stock price is at $110 when the option pays off, Rubinstein earns a return of 500 percent on her investment in the call. With an investment of $1,000 in shares, Rubinstein's return would be only 120 percent. In contrast, if the share price is $40, Rubinstein loses 100 percent of her investment if she buys the call, but only 20 percent of her investment if she buys shares. This example makes it clear that some derivatives can dramatically magnify price changes in the underlying. For each dramatic gain with a derivative, there is a counterparty that makes an equally dramatic loss.

Our example shows that the payoff of an option is nonlinear. This nonlinearity is typical of many derivatives. It complicates analysis of both the pricing and the risk of these financial instruments. Many derivatives debacles have come from the fact that firms and investors forgot that derivatives can be equivalent to leveraged positions in the underlying and that they have nonlinear payoffs.

### 1.2.2. Forward contracts

Because unexpected losses due to a depreciation of the euro force Garman to reduce its R&D investment, Garman's shareholders benefit if Garman succeeds in reducing its exposure to unexpected decreases in the value of the euro. If Garman buys a put option with an exercise price of $1 per euro, it can sell its euros for a least $100 million. To obtain this insurance, Garman pays the option premium. A forward contract enables Garman to eliminate its exposure to the euro completely without having to pay an option premium. The price specified in a forward contract is called the forward price. If the forward contract obligates Garman to sell €100 million at a price of $1 per dollar, it receives $100 million at maturity regardless of the price of the euro at that time. If it buys the put, Garman benefits from increases in the price of the euro. In contrast, with the forward contract, Garman's cash flow is the same irrespective of how much the euro appreciates or depreciates.

Garman's unhedged cash flow depends on the price of the euro in six months. Whenever a firm's cash flow depends on a variable, price, or quantity that can change unexpectedly for reasons beyond one's control, the variable is called a **risk factor**. The cash flow's **exposure** to a risk factor is the sensitivity of cash flow to unexpected changes in a risk factor. For a given exposure, a change in the risk factor increases cash flow approximately by the change in the risk factor times the exposure. Identifying the important risk factors for a firm and estimating the exposure of the firm's cash flow or of the firm's value to these risk factors is critical to the success of a risk management program. This task is often made difficult by the fact that exposures change as risk factors change unexpectedly. For example, a firm may export more as the dollar depreciates, so that its exposure to foreign currencies increases as the dollar depreciates. In the case of Garman, there is no uncertainty about the exposure. Garman has a fixed exposure of €100 million that ceases to exist after six months, so that the exposure has a maturity of six months.

Panel A of Figure 1.3 (on pages 12–13) shows the cash flow of Garman in six months if it does nothing to reduce its €100 million exposure. The market for a currency for immediate delivery is called the spot market or the cash market. Garman is **long** in euros, meaning that it benefits from an increase in the price of the euro. If Garman does nothing, its cash flow in six months is 100 million times the price of the euro on the cash market at that time.

Panel B of Figure 1.3 shows the payoff of a **short** forward position, which is a position to sell euros forward, at maturity of the contract in six months. The forward price is assumed to be $1. With the short forward position, Garman receives the forward price per euro delivered. The gain or payoff from the short forward position per unit is therefore the forward price minus the cash market price of the euro in six months. Garman's gain from the short forward position increases as the dollar price of the euro falls. If the euro is at $1.10 at maturity, Garman agreed to deliver euros worth $1.10 per unit at the price of $1, so that it loses $0.10 per unit or $10 million on the forward contract. In contrast, if the euro is at $0.90 at maturity, Garman receives $1 per unit for something worth $0.90 per unit, thereby gaining $10 million on the forward contract.

Panel C of Figure 1.3 shows Garman's cash flow in six months if it sells the euros forward. In six months, Garman sells the euros for $100 million. This cash flow can be decomposed into two pieces: what Garman would have received had it not sold the euros forward and the gain from the forward contract. The gain from the forward contract exactly offsets the shortfall Garman would have made relative to $100 million if it had sold the euros on the cash market.

A financial position that reduces the risk resulting from exposure to a risk factor is called a financial hedge. Here the financial hedge is the forward contract. A **perfect hedge** eliminates all the risk so that the hedged position, defined as the cash position plus the hedge (the euros plus the forward contract), has no exposure to the risk factor. In this example, the hedge is perfect.

Panel D of Figure 1.3 shows the cash flow of Garman if it buys a put instead of selling the euros forward. If Garman buys a put with exercise price equal to the forward price, its cash flow if the euro cash market price in six months is $0.90 will be $100 million minus the cost of the premium. This is because Garman exercises the put option to receive $100 million for its euros, but it had to pay a premium. Consequently, if Garman buys a put with an exercise price equal to the forward price, Garman's cash flow is less than with the forward contract unless the euro appreciates sufficiently so that the put is not exercised and the proceeds from selling the euro exceed the proceeds from selling the euros forward plus the cost of the option premium.

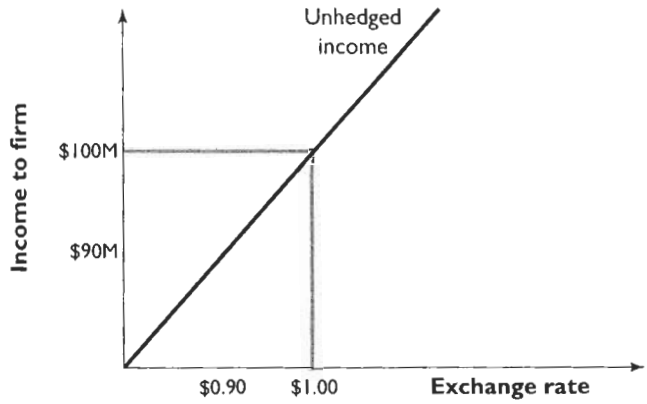
Whether Garman should reduce its exposure to the euro by selling euros forward or by buying a put depends on the specifics of the firm's situation. With buying the put, Garman earns less if the euro is lower than the forward price than if it sells euros forward. If these lower proceeds force Garman to cut back R&D, it should sell the euros forward. Suppose, however, that Garman would want to invest more in R&D if the euro appreciates because in that case it will export more to Europe. With this scenario, buying a put could be a better solution than selling euros forward because Garman would have a larger cash flow if the euro appreciates and hence would be better able to finance higher R&D expenditures.

*Figure 1.3*

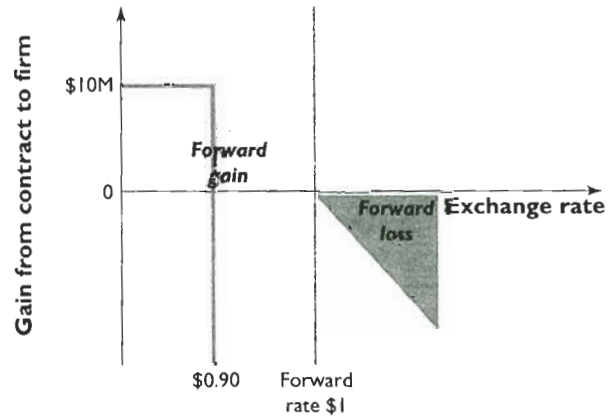
## Hedging with forward contract

Garman's income is in dollars and the exchange rate is the dollar price of one euro.

**Panel A. Income to Garman if it does not hedge.** Garman receives €100 million in six months, so that the dollar income is the dollar price of the euro times one million if the exporter does not hedge.




**Panel B. Forward contract payoff.** The forward price for the euro is $1. If the spot exchange rate is $0.90, the gain from the forward contract is the gain from selling €100 million at $1 rather than $0.90, which is $10 million.

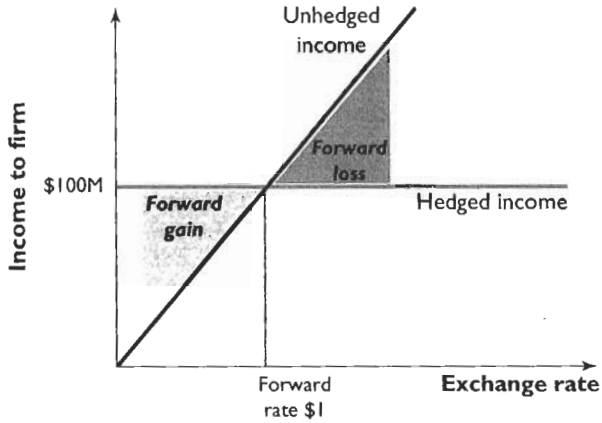



This example demonstrates four important lessons. First, through a financial transaction, Garman can eliminate all its risk without spending any cash to do so. This makes forward contracts extremely useful. The real world is more complicated than this, however. Finding the best hedge can be difficult and often the best hedge is not a perfect hedge.

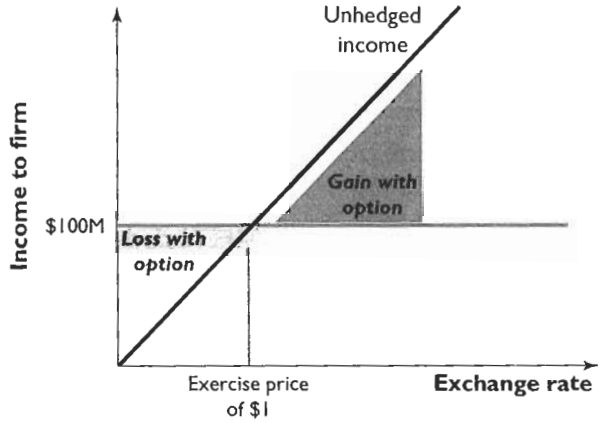
Second, the firm cannot consider the gains and losses of derivatives positions independently from the rest of the firm. When firms use derivatives to hedge, only firm value matters. To eliminate the risk of the hedged position, Garman has to be willing to make losses on derivatives positions. When it takes a forward position, its hedged cash flow entails no uncertainty—it is fixed. When the euro turns out to be worth more than the forward price, Garman loses on the forward

(continued) Figure 1.3

**Panel C. Hedged firm income.** The firm sells its euro income forward at a price of $1 per euro. It therefore gets a dollar income of $100 million for sure, which is equal to the unhedged firm income plus the forward contract payoff.




**Panel D. Comparison of income with put contract and income with forward contract.** Garman receives $100 million if it sells €100 million forward. With the put contract, Garman has to pay the premium, so that it receives less than $100 million if it exercises the put and gets to sell the euros at $1 per euro. If it does not exercise the put, it receives less than if it had not hedged, but more than with the forward hedge when the spot price of the euro exceeds the exercise price plus the option premium per euro.




contract. This is the case when the price of the euro is $1.10. The loss on the forward contract exactly offsets the gain made on the value of the euros received at maturity.

Third, the forward price must be such that the forward contract has no value at *origination*. That is, when Garman enters the forward contract, it agrees to sell euros at the forward price. The counterparty in the forward contract must agree to buy euros at the forward price. No money changes hands except for the agreed-upon exchange of euros for dollars at maturity of the contract. If the forward contract were to have value at origination of the contract for the exporter, it would

have to have negative value for someone on the opposite side, and there would be no one to be found to enter the contract. In this case, the counterparty would be better off not to enter the contract.

Fourth, Garman can decrease its euro exposure using different financial instruments. In this section, we saw that it could do so by selling euros forward or buying a put. We will see later that a firm in Garman's situation can use other financial instruments to decrease its exposure. The decision of which financial instrument to use to reduce an exposure depends on many considerations that we will explain in this book.

## 1.3. Using derivatives the right way for risk management

Rockfeller had it right when he said that one cannot get rich by saving. If we are to become rich, we have to take risks to exploit valuable opportunities where we have a comparative advantage. Firms and individuals must therefore avoid risks that are not profitable so that they can take on more risks that are advantageous. Derivatives enable them to shed risks and to take on risks cheaply.

To shed risks that are not profitable and take on the ones that are, it is crucial to understand the risks one is exposed to and to evaluate their costs and benefits. Individuals are not very good at thinking about risks without quantitative tools. We will overstate the importance of some risks and understate the importance of others. Most of us, for example, put too much weight on recent past experience. If a stock has been doing well, we will think that it will do unusually well in the future, so it has little risk. Most of us are reluctant to realize losses even though quantitative analysis shows that the tax code makes it advantageous for us to do so. People dealing with risk often take actions that cannot be justified on quantitative grounds. These tendencies are the subject of behavioral finance, which attempts to identify how the biases of individuals influence their portfolio decisions and asset returns.

To figure out which risks to bear and which risks to shed, one must have models to quantify the economic value of taking risks and shedding risks. Hence, to use derivatives the right way, one has to be able to make simple statements like: If I keep the exposure to weather risk, the value of the firm is X; if I shed the exposure to weather risk, the value of the firm after purchasing the appropriate financial instruments is Y; if Y is greater than X, I shed the weather risk. For individuals, it has to be that the measure of their welfare they focus on is affected by a risk, and they can establish whether shedding the risk makes them better off than bearing it.

To evaluate the economic value of taking risks and shedding risks, one has to be able to quantify risks. This requires statistics. One has to be able to trace the impact of risks on firm value or individual welfare. This requires economic analysis.

Finally, managers must know how a derivatives position will affect the risks the firm is exposed to. This requires understanding the instruments and how they are priced. A derivative might eliminate all of a risk, but it may also be priced so that one is worse off without the risk than with it. A derivatives salesperson could

argue that a derivative is the right one to eliminate a risk we are concerned about, but a more thorough analysis might reveal that the derivative actually increases our exposure to other risks so that we would be worse off purchasing it.

To use derivatives the right way for risk management, one has to define an objective function. For a firm, the objective function is generally to maximize shareholder wealth. Objective functions are of little use unless we can measure the impact of choices on the objective. We therefore have to be able to quantify how various risks affect our objective function. Doing so, we will find some risks that make us worse off and, perhaps, others that make us better off. Having figured out which risks are costly, we need to investigate whether there are derivatives strategies that can be used to improve our situation. This requires us to be able to figure out the impact of these strategies on our objective function. The world is not static. Exposures to risks change all the time. Consequently, derivatives positions that were appropriate yesterday may not be so today. This means that we must have systems in place that make it possible to monitor our risk exposures.

Using derivatives the right way means that we look ahead and determine which risks we should bear and how. Once we have decided which risks we should bear, nature has to run its course. If a derivative is bought to insure against losses, it is reasonable to think that about half the time, the losses one insures against will not take place, and the derivative will therefore not produce a gain to offset losses. The outcome of a derivatives transaction does not tell us whether we were right or wrong in entering the transaction any more than whether our house burns down or not tells us whether we were right or wrong to buy fire insurance. Houses almost never burn down; we almost always incur a loss on fire insurance. We buy the insurance because we know *ex ante* that we are better off shedding the risk of having to pay to replace the house.

In the Garman example, if Garman entered a forward contract, the euro ended up either above or below the forward price of $1. If it ended up above, Garman lost money on the contract. The temptation is to say that the firm made a poor use of derivatives because it lost money on the derivative. This is not the way to think about derivatives, however.

When the decision was made to use the derivative, Garman determined that it was better off hedging the currency risk. It had no information that allowed it to expect the euro to appreciate and hence could not act on such information; that's not Garman's business. When it entered into the forward contract, it concluded that the cost of cutting investment in response to a loss on the euro absent hedging was high enough to justify locking in the dollar value of its foreign currency receivable at the forward price. Nothing happened subsequently that changed the validity of Garman's rationale to hedge.

Garman could have been tempted to base its hedging decision on its view of how the exchange rate was going to evolve over the next six months. When basing hedges on forecasts, a firm has to remember that for every firm thinking that a currency is overvalued, there is another one thinking with the same amount of conviction that the currency is undervalued. A firm might be unusually good at forecasting exchange rates, but to beat the market, one has to be better than the investors who have the best information. This disqualifies most of us. If mutual fund managers whose job it is to beat the market do not do so on average, why

should a firm's employee or an individual investor think that he or she has a good enough chance of doing so that this should direct their choice of derivatives positions? Sometimes, we know something that has value and should trade on it. More often, though, we do not.

As it is easy and cheap to take positions in derivatives, a firm's position can change in an instant because of the actions of some individual who has authority to trade derivatives for the firm. This individual might even think that he is so good at forecasting future changes in exchange rates and interest rates that he should take financial positions to make profits for the firm. With no appropriate risk measures, such an individual can quickly take positions that could destroy the firm if things go wrong. It is therefore imperative for a firm that uses derivatives to monitor its derivative positions and to measure its risks accurately.

## 1.4. What does it take to use derivatives the right way for risk management?

Examples of the use of derivatives at two major companies demonstrate some of the issues that arise in managing risks. This preview of risk management in action shows the skills and tools a manager must master to manage risk and the issues he or she has to deal with.

### 1.4.1. Designing a foreign exchange hedging program at Merck

Merck is a multinational pharmaceutical company doing business in more than 100 countries. More than half of its sales are made abroad. Foreign sales are billed in local currencies. That is, a subsidiary selling in the United Kingdom would post UK prices and would bill its customers in pounds. Like all pharmaceutical companies, Merck has an extremely large R&D budget. A major concern of management is, as with Garman, that unexpected foreign exchange losses could force the company to retrench and to reduce its R&D expenditures, thereby becoming less competitive. Merck uses risk management to reduce the probability of such an outcome. Lewent and Kearney (1999) explain that when its risk management program was put in place, Merck addressed the issues in five steps:

**Step 1. Understand the distribution of exchange rates.** Exchange rates are risk factors. Merck is primarily interested in the likelihood of adverse exchange rate movements. It has to quantify the probability of such adverse exchange rate movements.

**Step 2. Estimate the impact of adverse exchange rate movements on the strategic plan.** Cash flows are exposed to foreign exchange movements. An adverse exchange rate movement decreases cash flows and hence limits the resources the company can use to fund R&D or to pay out as dividends.

**Step 3. Decide whether to hedge, depending on external considerations and internal considerations.** The main external consideration is Merck's ability to keep dividends growing. A strong dollar appreciation would reduce dollar income from foreign subsidiaries and possibly endanger dividend growth. The main internal consideration is Merck's ability

to finance R&D expenditures that are essential to the future of the corporation.

**Step 4. Choose the appropriate financial instruments.** Firms can use many different financial instruments to hedge a foreign exchange exposure. Managers must be able to evaluate how the various instruments can help them achieve their specific goals. Merck decided to use plain vanilla options in its hedging program. Its rationale was that options enabled it to benefit from a weak dollar, while complete hedging did not. To hedge revenue, Merck uses put options on local currencies. At the end of 1999, a 10 percent weakening of the dollar would have reduced the value of its portfolio of options used for hedging revenue by $86.7 million.

**Step 5. Determine how much to hedge.** Merck decided (1) to hedge on a multi-year basis, (2) to avoid options that had little chance to pay off at maturity, and (3) to hedge only partially. Consequently, with this hedging program, Merck kept some exposure to exchange rate changes.

### 1.4.2. Measuring risks at Microsoft

In 20 years, Microsoft went from an idea of a Harvard dropout to a company that had at times the largest market capitalization in the United States, worth at its 1999 peak more than half a trillion dollars. At that time, it had accumulated a portfolio of fixed-income securities managed by its own portfolio management group (PMG), strategic equity positions, and foreign exchange holdings in excess of $35 billion. It had $18 billion of net revenues to deal with. It had no debt. Yet, because of the nature of its business, a technological innovation conceived in a garage or a backroom somewhere could wipe out billions of equity value overnight. It was therefore essential for the firm to have resources to cope with unexpected challenges and to be able to measure financial risks and manage them.

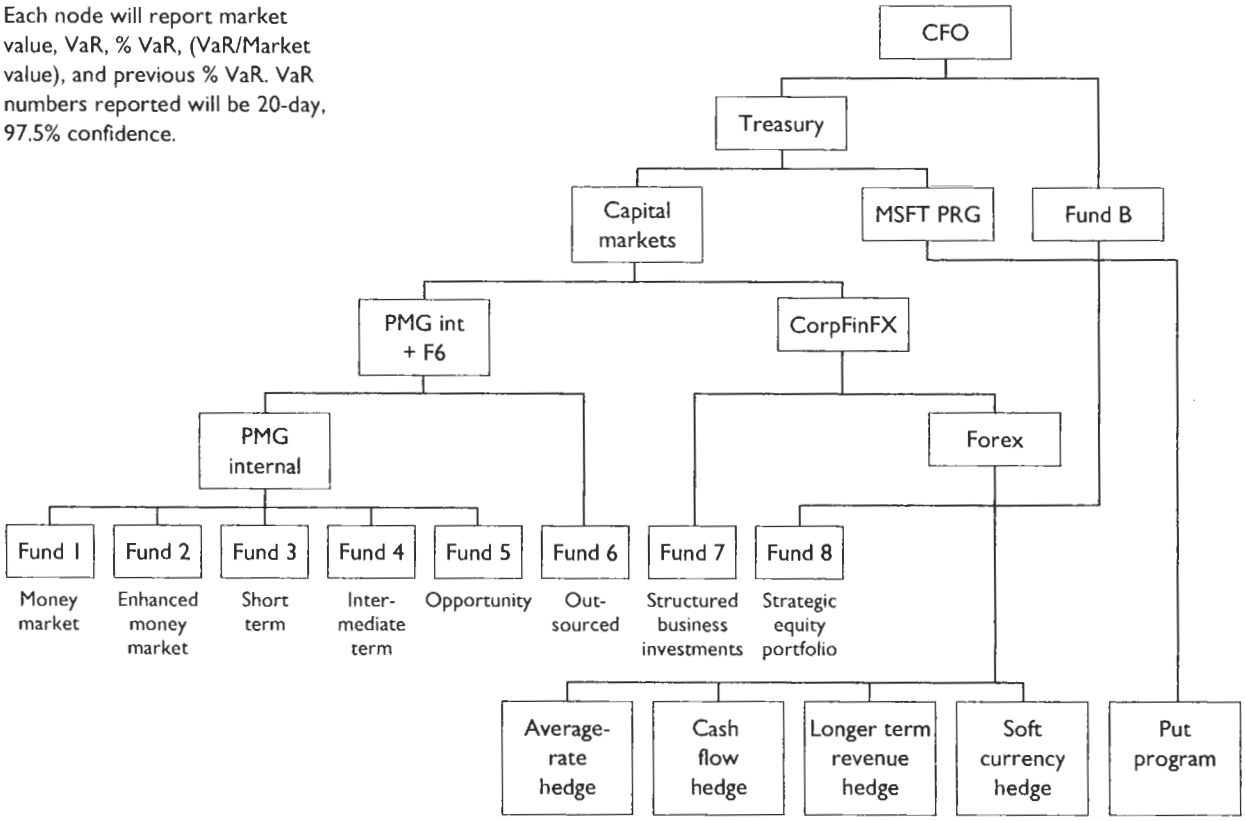
How can financial risk for such a company be measured? Microsoft built a financial risk reporting structure that looks like a tree. This tree is shown in Figure 1.4. The goal in building the tree was that at each node management and treasury would be able to identify, quantify, and manage financial risks.

To achieve its goal, Microsoft had to choose a risk measure. It chose to measure risk by the loss that, over a period of 20 days, would not be exceeded with a probability of 97.5 percent. An estimate of a loss for a portfolio over a period of time that is not exceeded at some probability level is called the value at risk, or VaR, of the portfolio. Historically, Microsoft had focused its risk management program on a number of different risks. It had an important options program for employees that created risks it was trying to manage. The company had huge foreign sales, with attendant foreign exchange exposures. It had a large investment portfolio. These various risks were managed separately. When it introduced VaR as a risk measure, Microsoft was able to start looking at risk in a holistic way; all risks were measured in the same way and could be evaluated at the company level, taking into account the interactions among and between the various risks the company was exposed to.

Microsoft installed systems that would enable it to compute estimates of VaR at all the nodes of the tree in Figure 1.4. Managers started the Gibraltar project

*Figure 1.4* **Microsoft's corporate tree**

Each node will report market value, VaR, % VaR, (VaR/Market value), and previous % VaR. VaR numbers reported will be 20-day, 97.5% confidence.



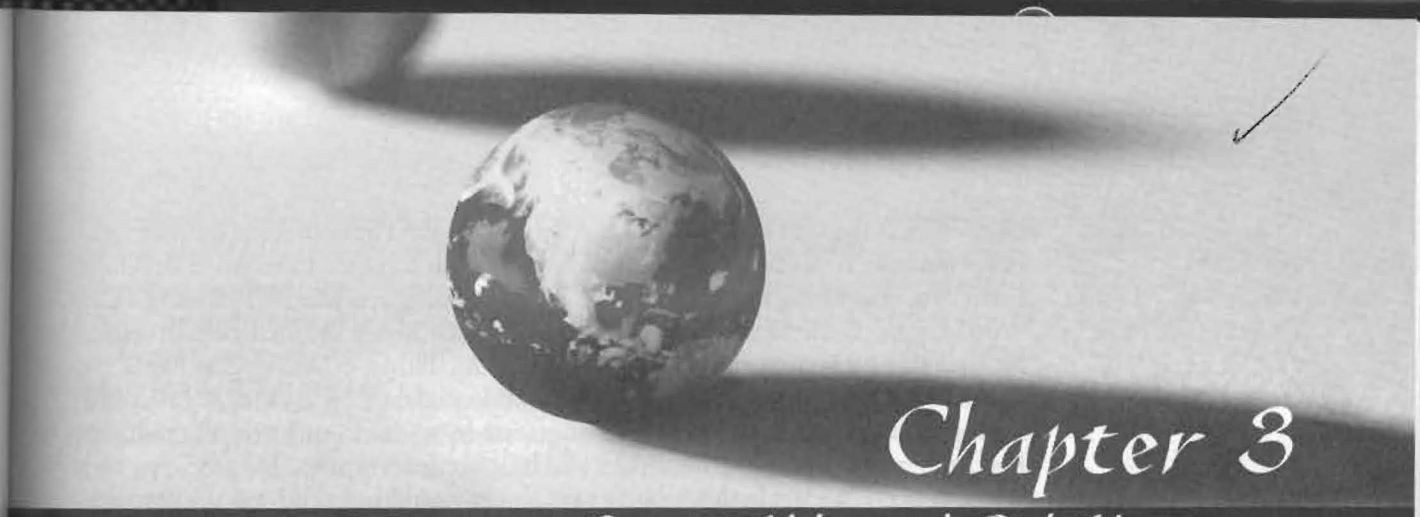

to establish an integrated system to capture data and provide statistics that could be used to evaluate it. The end product was a web-based system that enables executives to view the risk of the nodes of the tree online.

With this system, Microsoft knows what its financial risks are. Managers can continually monitor these risks and can decide what to do about them. To implement hedges, they use analytical options software that gives them the capability to design hedges using a variety of instruments. Microsoft typically uses forward contracts to hedge short-run exposures and options to hedge longer-run exposures. When it uses options to hedge revenues, it mostly uses average-rate options, a type of exotic option. The payoff of an average-rate call option per unit is the average exchange rate over a period of time minus the exercise price.

Microsoft's approach is to use only derivatives that it can price and understand. In its systems, Microsoft must be able to price the options it uses, monitor their risk, and design hedges using such options.

## 1.5. Learning to manage risks with derivatives the right way

This book has 19 chapters. Each chapter will help you to acquire the tools and skills you need to understand and implement risk management solutions such as



# Chapter 3

## Creating Value with Risk Management

### Chapter 3 Objectives

At the end of this chapter, you will:

1. Understand when risk management creates value for firms.
2. Know which types of risks a corporation should hedge to create value.
3. Be able to evaluate how much value risk management can create in a corporation.

Mr. Smith is the CFO of Software Inc. He has worked hard to keep up with new developments in finance. He recently attended an advanced executive development program where much time was spent discussing the Modigliani and Miller propositions. Understanding that shareholders can hedge on their own account, he has paid scant attention to risk management. However, looking at his firm's situation, he discovers that it will not be able to make use of a valuable tax shield arising from past losses because exchange rate losses have unexpectedly reduced his firm's net income. The tax shield will be gone forever after this year. Yet, had the firm been profitable this year, the tax shield would have allowed the corporation to reduce its tax bill by $50 million. He realizes that if he had been able to hedge his income against exchange rate fluctuations, Software Inc. would have been richer by $50 million. Instead, because he had not hedged, $50 million of shareholder wealth walked out the door. In this chapter, we show that there are many reasons to hedge.

A risk management program cannot increase firm value when it costs the same to bear a risk within the firm or outside the firm. We established this result, called *the risk management irrelevance proposition*, in Chapter 2. The irrelevance proposition holds when financial markets are perfect. If the proposition holds, any risk management program that a firm puts in place can be replicated by any investor through "homemade" risk management. The risk management irrelevance proposition is useful because it allows us to find out when homemade risk management is not equivalent to risk management by the firm. This is the case whenever risk management by a firm affects firm value in a way that investors cannot mimic. In this chapter, we identify situations where there is a wedge between the cost of bearing a risk within the firm and the cost of bearing it outside the firm. Such a wedge requires the presence of financial markets imperfections (perfect markets have no frictions—no transactions costs, no taxes, perfect competition, no costs of writing contracts).

Chapter 2 uses the example of a gold-producing firm. We continue that example here. Pure Gold Inc. is exposed to gold price risk. It can bear that risk within the firm. This means the firm has lower income if the price of gold is unexpectedly low and higher income if it is unexpectedly high. If the irrelevance proposition holds, the only cost of bearing this risk within the firm is that shares are worth less if gold price risk is systematic risk, because in this case shareholders require a risk premium to compensate them for gold price risk. Similarly, the only cost to the firm of having gold price risk borne outside the firm is that the firm has to pay a risk premium to induce the capital markets to take that risk. The risk premium the capital markets require is the same the shareholders require. Consequently, it makes no difference for firm value whether the gold price risk is borne by shareholders or by the capital markets, which is what the risk management irrelevance proposition states.

For risk management to increase firm value, it must be more expensive to take a risk within the firm than to pay the capital markets to take it. For Pure Gold, risk management creates value if an unexpectedly low gold price entails costs for the firm that it would not have for the capital markets. Suppose that with an unexpectedly low gold price, the firm does not have funds to invest, and hence has to give up valuable projects because it would be expensive for the current

shareholders to raise funds in the capital markets with such a low gold price. Thus, shareholders not only lose income now with unexpected low gold prices, but they also lose future income because the firm cannot take advantage of investment opportunities. Pure Gold bears an extra, indirect, cost or burden from the low gold prices. Indirect costs resulting from financial losses are called **deadweight costs**.

To understand deadweight costs, suppose you asked yourself how Pure Gold could be put back in the situation it would have been in had gold prices not been low. If all it takes is to make up the loss Pure Gold experienced on its sales of gold, then there are no deadweight costs—no additional losses caused by the low gold prices. However, if, in addition, Pure Gold has to be compensated for profits it did not earn because of investments it could not make, there are deadweight costs.

The reason risk management creates value for Pure Gold if there are deadweight costs associated with gold price risk is that risk management reduces or eliminates deadweight costs. If the gold price risk is borne by the capital markets, Pure Gold does not incur additional costs resulting from low gold prices since it makes no losses from low gold prices. In this case, the cost of putting the gold price risk off on the capital markets is less than the cost the firm will pay if it bears the risk within the firm and sacrifices future opportunities by not being able to invest when the gold price is low.

In this chapter, we investigate how a firm can use risk management to increase firm value. We discuss the reasons why a firm might find it more expensive to bear a risk within the firm than pay the capital markets to bear that risk. We thus show the sources of the benefits of risk management.

In the previous chapter, we gave the example of Homestake as a gold mining firm that had a policy of not hedging its gold price exposure. As you saw, management based its policy on the belief that Homestake's shareholders value gold price exposure. We showed that this belief is wrong because investors can get gold price exposure without Homestake on terms at least as good as those that Homestake offers, and most likely better. So, is Hometake's value lower than it would have been with hedging? Throughout this chapter, for each source of value of hedging we document, we investigate whether this source of value applies to Homestake.

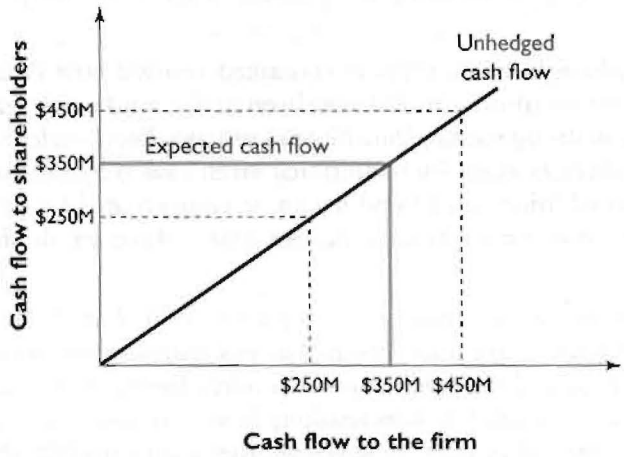
In the next chapter, we integrate these various sources of gain from risk management to build an integrated risk management strategy.

## 3.1. Bankruptcy costs and costs of financial distress

In our analysis of the value of risk management in Chapter 2, we take the distribution of Pure Gold's cash flow before hedging (the cash flow from operations) as a given. We assume that it sells one million ounces of gold at the end of the year and then liquidates. Pure Gold has no debt. The gold price is assumed to be normally distributed with a mean of $350 per ounce. There are no operating costs for simplicity. All the cash flow accrues to the firm's shareholders. This situation is represented by the straight line in Figure 3.1, where cash flow to

*Figure 3.1* Cash flow to shareholders and operating cash flow

The firm sells one million ounces of gold at the end of the year and liquidates. There are no costs. The expected gold price is $350.




Pure Gold is on the horizontal axis and cash flow to the holders of financial claims against it is on the vertical axis. In this case, the only claimholders are the shareholders. In perfect financial markets, all cash flows to the firm accrue to the firm's claimholders, so there is no gain from risk management.

At the end of the year, Pure Gold distributes the cash flow to its owners, the shareholders, and liquidates. If the firm hedges by selling its production at the forward price, the shareholders get the proceeds from selling the firm's gold production at the forward price. Suppose the forward price is $350. If the gold price turns out to be $450, for example, the hedged firm receives $350 per ounce by delivering on the forward contract, while the unhedged firm would receive $450 per ounce.

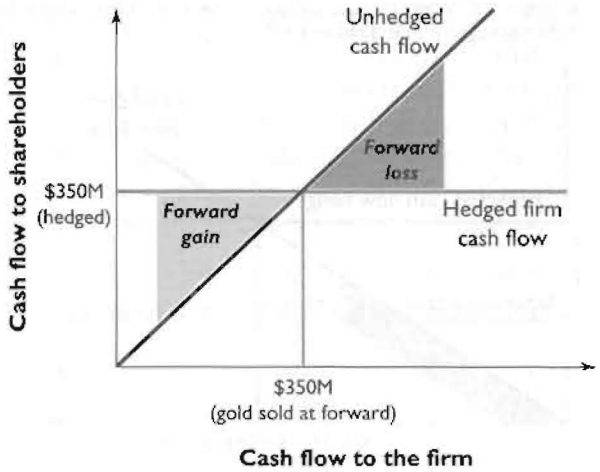
The shareholders, however, can obtain for themselves the payoff of the unhedged firm when the firm is hedged and vice versa. This is shown in Figure 3.2. An investor who owns the hedged firm and takes a long forward position on personal account receives $350 per ounce of gold from the hedged firm plus ($450 – $350) per ounce from the forward contract, for a total payoff of $450 per ounce, which is the payoff per ounce for the unhedged firm. Hence, even though the firm is hedged, investors can create for themselves the payoff of the unhedged firm.

Now, suppose Pure Gold has some debt. We still assume that markets are perfect, that the distribution of the cash flow from operations is given, and that there are no taxes. At the end of the year, the cash flow to the firm is used first to pay off the debtholders, and then shareholders receive what is left over. The firm's claimholders still receive all of the firm's cash flow, and the firm's cash flow is not changed by leverage, but there are now two groups of claimholders, debtholders

## Creating the unhedged firm out of the hedged firm

*Figure 3.2*

The firm produces one million ounces of gold. It can hedge by selling one million ounces of gold forward. The expected gold price and the forward price are $350 per ounce. If the firm hedges and shareholders do not want the firm to hedge, they can recreate the unhedged firm by taking a long position forward in one million ounces of gold.



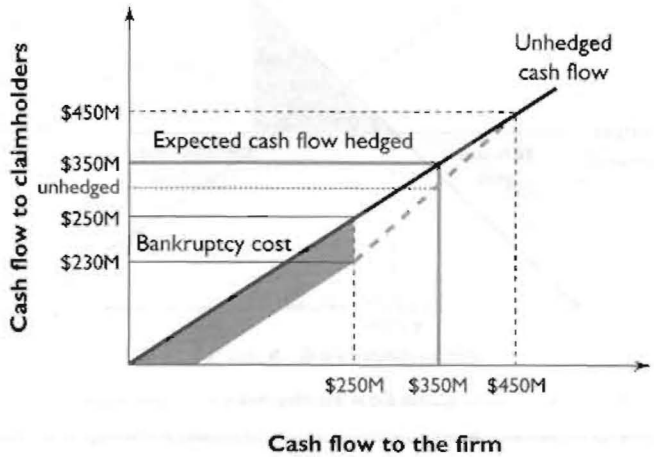

and shareholders. Leverage does not affect firm value. It simply specifies how the pie—the firm's operating cash flow—is divided among its claimants—the debtholders and the shareholders. Since the cash flow to claimholders is the firm's entire cash flow, risk management does not affect firm value.

In the real world, it is costly for firms to file for bankruptcy and renegotiate debt. Firms have to hire lawyers, incur court costs, and need to pay for all sorts of financial advice. Costs incurred as a result of a bankruptcy filing are called **bankruptcy costs**. The present value of future bankruptcy costs reduces the value of a firm that has debt relative to one that does not. While there are benefits to leverage, for the time being we ignore them. As shown in Figure 3.3, these bankruptcy costs create a "wedge" between cash flow to the firm and cash flow to the firm's claimholders. This wedge corresponds to the bankruptcy costs incurred by the owners.

The extent to which bankruptcy costs affect firm value depends on their extent and on the probability that the firm will have to file for bankruptcy. The probability that a firm will be bankrupt is the probability that it will not have enough cash flow to repay the debt. We know how to compute this probability for a normally distributed cash flow. Figure 3.4 shows how the distribution of cash flow from operations affects the probability of bankruptcy. If Pure Gold hedges its risk completely, it reduces its cash flow volatility to zero because the claimholders receive the present value of gold sold at the forward price. In this case, the probability of bankruptcy is zero and the present value of bankruptcy costs is also zero. As cash flow volatility increases, the present value of bankruptcy costs increases because bankruptcy becomes more likely. This means that the present value of cash flow to Pure Gold's claimholders falls as cash flow volatility increases.

## Figure 3.3 Cash flow to claimholders and bankruptcy costs

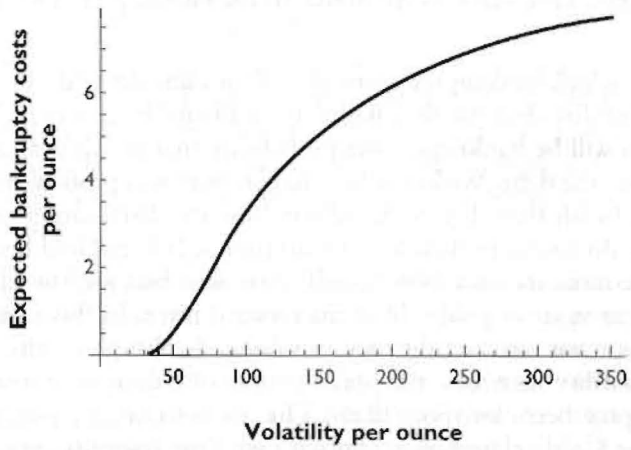
The firm sells one million ounces of gold at the end of the year and liquidates. There are no transactions costs. The expected gold price is $350. Bankruptcy costs are $20 million if cash flow to the firm is $250 million. Suppose that the firm can have a cash flow of $250 million with probability $p$ or a cash flow of $450 million with probability $1 - p$. Expected cash flow of the unhedged firm is given by the equation $p \times \$230M + (1 - p) \times \$450M$ and is plotted by the dotted line. The case where the forward price of gold is $350 and equal to expected gold price corresponds to $p = 0.5$. With this case, expected cash flow of the hedged firm is $350 million and expected cash flow of the unhedged firm is $340 million.




Therefore, by hedging, Pure Gold increases its value; that is, it does not have to pay bankruptcy costs, and hence its claimholders get all of the firm's cash flow. In this case, homemade risk management by the firm's claimholders is not a substitute for the firm's risk management. If the firm does not reduce its risk, its value

## Figure 3.4 Expected bankruptcy costs as a function of volatility

The firm produces one million ounces of gold and then liquidates. It is bankrupt if the price of gold is below $250 per ounce. The bankruptcy costs are $20 per ounce. The gold price is distributed normally with expected value of $350. The volatility is in dollars per ounce.



is lower by the present value of bankruptcy costs. Homemade risk management can do nothing about this deadweight cost of low gold prices.

### 3.1.1. Bankruptcy costs and firm value

We can use the present value equation to show that risk management increases firm value when the only financial market imperfection is the presence of bankruptcy costs that affect firm value. We therefore assume that markets are perfect for hedging instruments traded in capital markets, so that hedging involves no transaction costs. Remember that in the absence of bankruptcy costs, the firm's claimholders receive the cash flow at the end of the year when the firm is liquidated. Under our new assumptions, the claimholders receive the cash flow only if the firm is not bankrupt. Denote this cash flow by $C$. If the firm is bankrupt, the claimholders receive $C$ minus the bankruptcy costs. Consequently, the value of the firm is now:

$$\textbf{Value of firm} = PV(C - \textbf{Bankruptcy costs})$$

We know from Chapter 2 that the present value of a sum of cash flows is the sum of the present values of the cash flows. Consequently, the value of the firm is equal to:

$$\begin{aligned}\textbf{Value of firm} &= PV(C) - PV(\textbf{Bankruptcy costs})\\ &= \textbf{Value of firm without bankruptcy costs}\\ &\quad - \textbf{Present value of bankruptcy costs}\end{aligned}$$

Let's now consider the impact of risk management on firm value. If the hedge eliminates all risk, then the firm does not incur the bankruptcy costs. Hence, the cash flow to the firm's owner is what the cash flow would be in the absence of bankruptcy costs, which is $C$. This means that with such a hedge the claimholders get the present value of $C$ rather than the present value of $C$ minus the present value of bankruptcy costs. Assuming that no market imperfections affect the cost of hedging instruments, the gain from risk management is:

$$\begin{aligned}\textbf{Gain from risk management} &= \textbf{Value of firm hedged}\\ &\quad - \textbf{Value of firm unhedged}\\ &= PV(\textbf{Bankruptcy costs})\end{aligned}$$

A simple example of the benefit of hedging is as follows. We assume that the interest rate is 5 percent and that gold price risk is unsystematic risk. The forward price is \$350. Because gold price risk is unsystematic risk, the forward price is equal to the expected gold price (from the analysis in Chapter 2). As before, Pure Gold produces one million ounces of gold. Consequently, $PV(C)$ is equal to \$350M/1.05, or \$333.33 million. The present value of the hedged firm is the same (this is because expected cash flow, $E(C)$, is equal to one million times the expected gold price, which is the forward price).

To get the present value of the bankruptcy costs, we must specify the debt payment and the distribution of the cash flow. Let's say that the bankruptcy costs are \$20 million, the face value of debt is \$250 million, the gold price is normally distributed, and its volatility is 20 percent. The firm is bankrupt if the gold price

falls below \$250. The probability that the gold price will fall below \$250 is 0.077 using the approach developed in Chapter 2. Consequently, the expected bankruptcy costs are 0.077 × \$20M, or \$1.54 million. By the use of risk management, Pure Gold ensures that it is never bankrupt, thus increasing its value by the present value of \$1.54M. Since gold price risk is assumed to be unsystematic risk, we discount the expected bankruptcy costs at the risk-free rate of 5 percent to get a present value of bankruptcy costs of \$1.47 million (\$1.54M/1.05).

In the presence of bankruptcy costs, the risk management irrelevance theorem no longer holds. The cost to Pure Gold of bearing gold price risk is \$1.47 million. Because we assume that gold price risk is diversifiable, the cost of having the capital markets bear this risk is zero. The capital markets therefore have a comparative advantage over the firm in bearing gold price risk.

Note that if gold price risk is systematic risk, capital markets will charge a risk premium for bearing the gold price risk—the same risk premium that shareholders charge in the absence of bankruptcy costs. Hence, the capital markets still have a comparative advantage for bearing risk; it is measured by the bankruptcy costs saved by having the capital markets bear the risk. There is nothing that shareholders can do on their own to avoid the impact of bankruptcy costs on Pure Gold's value, so homemade risk management cannot eliminate these costs.

### 3.1.2. Bankruptcy costs, financial distress costs, and the costs of risk management programs

A study of bankruptcy for 31 firms over the period from 1980 to 1986 by Weiss (1990) finds an average ratio of direct bankruptcy costs to total assets of 2.8 percent, with a high of 7 percent. Other researchers find similar estimates. Bankruptcy also entails large indirect costs. Managers spend much of their time dealing with the firm's bankruptcy proceedings instead of managing operations. Managers of a firm in bankruptcy lose control of some decisions. They might not be allowed to undertake costly new projects, for example.

Many of these indirect costs start accruing as soon as a firm's financial situation becomes unhealthy. The costs firms incur because of a poor financial situation are called **costs of financial distress**. Costs of financial distress can occur even if the firm never files for bankruptcy or never defaults. Managers have to think about finding ways to conserve cash to pay off debtholders. They might cut investment, which means the loss of future profits. Potential customers may become reluctant to deal with the firm, leading to losses in sales.

Our analysis of the benefits of risk management in reducing bankruptcy costs holds for all costs of financial distress also. Any time costs of financial distress divert cash flow away from the firm's claimholders, they reduce firm value. Reducing firm risk by minimizing the present value of costs of financial distress naturally increases firm value.

Reducing the costs of financial distress is one of the most important benefits of risk management. Consequently, we study in more detail how risk management can be used to reduce specific costs of financial distress in later sections in this chapter.

In the example, Pure Gold eliminates all of its bankruptcy costs through risk management. If managers identify other costs of financial distress that occur

when the firm's cash flow is low, they could eliminate them as well through risk management. Some risks, however, are too expensive to reduce through risk management. In the absence of risk management costs, though, we would always eliminate all bankruptcy and financial distress risks.

There are transaction costs of taking positions in forward contracts. The transaction costs of risk management increase the cost of paying the capital markets to take the risk. As transaction costs increase, risk management becomes less attractive. If the firm bears a risk internally, it does not pay these transaction costs.

### 3.1.3. Bankruptcy costs, Homestake, and Enron

At the end of the 1990 fiscal year, Homestake had cash balances of more than $300 million. Its long-term debt was $72 million, and it had unused credit lines amounting to $245 million. Homestake could have repaid all its long-term debt and still have had large cash balances. Bankruptcy was not likely. Suppose it had more long-term debt, though. Would bankruptcy and financial distress costs then be a serious issue?

Homestake's assets are its mines and its mining equipment. These assets do not lose value if Homestake defaults on its debt. If it makes sense to operate the mines, the mines will be operated, whoever owns them. Neither bankruptcy costs nor financial distress costs in this case provide an important reason for Homestake to practice risk management. Homestake is an example of a firm for which the reduction of financial distress costs is not an important benefit of risk management.

For many financial institutions, the mere appearance of some possibility of financial distress is enough to threaten the firm. In a bank, concerns of financial distress could prompt a run on the bank.

An example of how financial distress can lead to disaster is that of Enron. Enron was the seventh largest firm in the United States. It had a large and profitable online trading business—it traded energy, broadband, credit risks, and other goods. When its management lost credibility and its debt was downgraded from investment grade in November 2001, this started a sequence of events that led Enron to file for bankruptcy within weeks because financial distress removed the underpinnings of its trading business. Who wants to trade with an entity that has a significant probability of default?

## 3.2. Taxes and risk management

Risk management creates value when it is more expensive to take a risk within the firm than to pay the capital markets to bear that risk. Corporate taxes are a good example. These taxes can increase the cost of taking risks within the firm.

We all accept that if a dollar of taxes has to be paid, paying it later is better than paying it sooner. While derivatives are sometimes used to create strategies that move income to later years, for now we focus on how managing risk, as opposed to timing income, can reduce the present value of taxes.

To understand the argument, it is useful to think about one important tax planning practice. If you know that in some future year your tax rate will be lower, you should try to recognize income in that year rather than today or in

years your tax rate is higher. Pension plans are the prime example. If you can defer taxation on current income through a pension plan, you do so assuming that your retirement years' tax rate will be lower than the tax rate in your high-earning years.

Risk management, rather than altering in which tax year income is recognized, aims to alter the risks one takes to decrease expected tax payments in a given year. Suppose there are some outcomes—often called states of the world in finance—where this year's income is high and taxed at a high rate, and other outcomes where it is low and taxed at a low rate. For instance, if gold prices are high, gold companies have high income and a high tax rate. If we can rearrange the risks we take so that we have less income when the tax rate is high and more income when the tax rate is low, the present value of taxes paid is reduced.

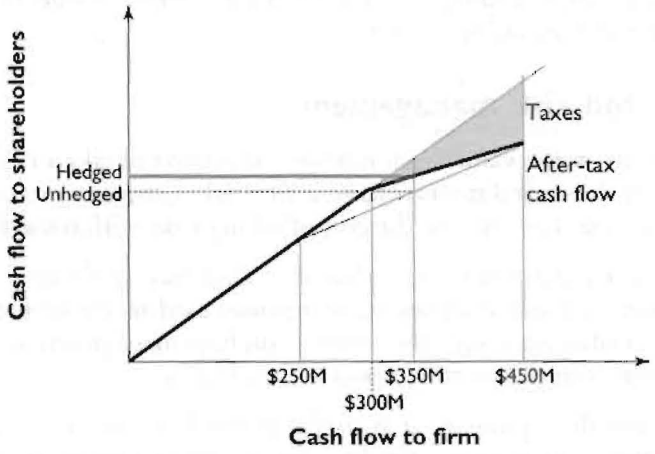
Let's consider Pure Gold again. A firm generally pays taxes only if its revenue exceeds some level. Let's assume that Pure Gold pays taxes at the rate of 50 percent on the cash flow in excess of $300 million and does not pay taxes if its cash flow is below $300 million. For simplicity, we assume in this section that it is an all-equity firm, so there are no bankruptcy costs.

Figure 3.5 graphs Pure Gold's after-tax cash flow as a function of the pretax cash flow. We see a difference between the firm's operating cash flow and what its shareholders receive, and this is due to taxes. Now, assume further that there is a 50 percent chance the gold price will be $250 per ounce and a 50 percent chance it will be $450, so the expected gold price is $350. Assuming that gold price risk is unsystematic risk, the forward price for gold is the expected gold price of $350. As before, the interest rate is 5 percent.

In the absence of taxes, the value of Pure Gold is the present value of the expected cash flow, $350 million discounted at 5 percent, or $333.33 million.

## Figure 3.5 Taxes and cash flow to shareholders

The firm pays taxes at the rate of 50 percent on cash flow in excess of $300 per ounce. For simplicity, the price of gold is either $250 or $450 with equal probability. The forward price is $350.



With taxes, the present value of the firm for its shareholders is reduced, because the firm pays taxes when the gold price is \$450. In this case, the firm pays taxes of 0.5(\$450 – \$300)1M, or \$75 million. With taxes, the value of the firm's equity is:

$$
\begin{aligned}
\textbf{Value of firm with taxes} &= \textbf{\textit{PV}(Gold sales – Taxes)} \\
&= \textbf{\textit{PV}(Gold sales) – \textit{PV}(Taxes)} \\
&= \textbf{\textit{PV}(Firm without taxes) – \textit{PV}(Taxes)} \\
&= \textbf{\$333.33M} - 0.5 \times \textbf{\$75M/1.05} \\
&= \textbf{\$333.33M – \$35.71M} \\
&= \textbf{\$297.62M}
\end{aligned}
$$

Let's figure what it costs shareholders to have the firm bear gold price risk compared to having the firm lay off the gold price risk by selling gold forward. To do this, we have to compare firm value if gold is sold on the spot market after it is produced with firm value if gold is sold at the forward price. Remember that the gold price can be either \$250 or \$450. If the gold price is \$250, the shareholders get \$250 per ounce. If the gold price is \$450, they get \$375 per ounce (\$450 minus taxes at the rate of 50 percent on \$150). The expected cash flow to the shareholders is therefore (0.5 × \$250) + (0.5 × \$375), or \$312.5 per ounce. Since the expected cash flow would be \$350 absent taxes, expected taxes are \$37.5 per ounce. If the gold price is fixed at the forward price instead, so that cash flow is not volatile, shareholders receive \$325 per ounce once they pay taxes at the rate of 50 percent on \$50. In this case, expected taxes are \$25 per ounce. Taking present values, the equity value is \$309.52 per ounce if gold is sold at the forward price and \$297.62 if gold is sold at the spot market price. Hence, it costs the shareholders \$11.90 per ounce for having the firm bear the gold price risk, or \$11.90 million for the firm as a whole.

The reason the firm saves taxes through risk management is straightforward. If the firm's income is low, the firm pays no taxes. If the firm's income is high, it pays taxes. If Pure Gold shifts a dollar from when income is high to when income is low, it saves the taxes it would pay on that dollar when the income is high. In our example, shifting income of a dollar from when income is high to when income is low saves \$0.50 with probability 0.5.

Homemade risk management cannot work in this case. If the firm does not use risk management to eliminate its cash flow volatility, its expected taxes are higher by \$12.5 million. This is money that leaves the firm and does not accrue to shareholders. Through homemade risk management, shareholders can eliminate the volatility in the share price resulting from gold price volatility, but they cannot affect the taxes the firm pays, so that the tax saving from risk management at the firm level cannot be obtained by shareholders through homemade risk management.

Let's figure out how shareholders would practice homemade risk management. Shareholders receive \$375 per share or \$250 per share from the firm with equal probability. To eliminate the gold price risk resulting from holding a share of Pure Gold, a shareholder can take a forward position so that the hedged payoff is the

same whatever the gold price. Let $h$ be the short forward position per ounce. Remember that the forward price is assumed to be \$350 per ounce. Therefore, a short forward position of one unit pays \$350 – \$250 if the gold price is \$250 and \$350 – \$450 if the gold price is \$450. To eliminate the impact of gold price risk, the shareholder must choose $h$ so that the income is the same whatever the gold price:

$$\$250 + h(\$350 - \$250) = \$375 + h(\$350 - \$450)$$

Solving for $h$, we get 0.625. By selling short 0.625 ounces forward, the shareholder guarantees a payoff of \$312.5 per ounce at the end of the year. If the gold price is \$250 per ounce, the shareholder receives \$250 per share from the firm and 0.625 × (\$350 – \$250), or \$62.50, from the forward position. This amounts to \$312.50. The shareholder is clearly better off if the firm hedges directly, since in that case she gets \$325, or \$12.50 more than if the firm does not hedge and she practices homemade risk management.

### 3.2.1. The tax argument for risk management

The tax argument for risk management is straightforward: If it moves a dollar away from a possible outcome in which the taxpayer is subject to a high tax rate and shifts it to a possible outcome where the taxpayer incurs a low tax rate, a firm or an investor reduces the present value of taxes to be paid. The tax rationale for risk management applies whenever income is taxed differently at different levels. The tax code introduces complications in the analysis. Some of these complications decrease the value of hedging, whereas others increase it. Some of these complications are discussed next.

1. **Carrybacks and carryforwards.** A firm that has negative taxable income can offset future or past taxable income with a loss in this tax year, subject to limitations. One limitation is that losses can be carried back or carried forward only for a limited number of years. In addition, no allowance is made for the time value of money. To see the importance of the time value of money, suppose a firm makes a gain of \$100,000 this year and then a loss of \$100,000 in three years. It has no other income. The tax rate is 30 percent. Three years from now, the firm can offset the \$100,000 gain of this year with its loss. But it must pay \$30,000 in taxes this year, and it gets back only \$30,000 in three years, so it loses the use of the money for three years.

2. **Tax shields.** There is a wide variety of tax shields. One is the tax shield on interest paid. Another is the tax shield on depreciation. Firms also have tax credits. All these complications mean that a firm's marginal tax rate can be quite variable. Further, tax laws change, so at various times firms and investors know that taxes will rise or fall. In such cases, the optimal risk management program is one that increases cash flows when taxes are low and reduces them when they are high.

3. **Personal taxes.** Our discussion ignored taxes paid by investors. Suppose that taxes paid by investors decreased the forward price. In this case, hedging would be less advantageous at the firm level because the forward price would be less attractive. There is no reason to suspect that taxes

create biases in the prices of forward contracts—or other derivative contracts—that make hedging at the firm level unattractive.

It is difficult to capture all real-life complications in an analytical model to evaluate the importance of the tax benefits of risk management. To cope with this problem, Graham and Smith (1999) use a simulation approach instead. They do not take into account personal taxes, but otherwise they incorporate all the relevant features of the tax code. They simulate a firm's income, and then evaluate the tax benefit of hedging. For about half the firms, there is a tax benefit from hedging. The typical benefit is that a 1 percent reduction in the volatility of taxable income for a given year reduces the present value of taxes by 1 percent.

### 3.2.2. The tax benefits of risk management and Homestake

In 1990, Homestake paid taxes of $5.827 million. It made a loss on continuing operations because it wrote down its investment in North American Metals Corporation. Taxation in extraction industries like minerals and oil and gas companies is notoriously complicated. However, the annual report shows why Homestake's tax rate differs from the statutory tax rate of 34 percent as follows (in thousands of dollars):

| | |
|---|---|
| Homestake loss: $13,500 at 34% would yield taxes of | $ (4,600) |
| Depletion allowance | (8,398) |
| State income taxes, net of federal benefit | (224) |
| Nondeductible foreign losses | 18,191 |
| Other, net | 858 |
| Total | $ 5,827 |

Homestake paid taxes even though it lost money. The exact details of the nondeductible foreign losses are not available from the annual report. Therefore, we cannot say for sure that risk management could have decreased taxes paid by Homestake. However, risk management enables a firm to shift income from states of the world with high tax rates to states of the world with low tax rates. Perhaps risk management could have enabled Homestake to avoid paying taxes while it was making a loss.

Decreases in the price of gold could easily lead to a situation where Homestake would make losses. Avoiding these losses would smooth out taxes over time and hence would increase firm value. Based on the information in the annual report, we cannot quantify this benefit. Petersen and Thiagarajan (2000) compare American Barrick and Homestake in great detail. They find that Homestake has a tendency to time the recognition of expenses when gold prices are high to smooth income. Obviously, in the year discussed here, smoothing income that way did not prevent Homestake from having to pay taxes while it was making a loss.

## 3.3. Optimal capital structure and risk management

Generally, interest paid is deductible from income. A levered firm that pays interest on debt therefore pays less in taxes than one without interest payments for the

same operating cash flow. Debt has a tax benefit, which increases the value of the levered firm relative to the value of the unlevered firm. In the presence of costs of financial distress, an increase in the firm's debt has an offsetting cost resulting from the increased likelihood of financial distress. Risk management enables the firm to have a higher debt level, and hence a greater tax shield from debt, for any likelihood of financial distress.

### 3.3.1. The tax shield of debt, costs of financial distress, and risk management

Let's see how risk management enables a firm to increase its tax benefits from debt without increasing its probability of financial distress. Suppose that the costs of financial distress are so high for Pure Gold that it is never worthwhile for Pure Gold to issue an amount of debt so that it defaults when it sells gold for \$250. Absent risk management, Pure Gold can issue risk-free debt so that its debt payments at maturity are \$250 million. It can use the proceeds of the debt issue to pay a dividend to shareholders. With that debt level, the interest rate on debt is the risk-free rate of 5 percent, so that Pure Gold pays interest of \$11.90 million and borrows \$239.10 million. The firm's value for its shareholders is the present value of $0.5 \times \$250M + 0.5 \times [\$450M - 0.5 \times (\$450M - \$300M - \$11.90M)]$, or \$315.475 million.

Using risk management, Pure Gold can issue more risk-free debt and therefore reduce the present value of its tax payments. With risk management, it can lock in pre-tax income of \$350 million and therefore can commit to pay \$350 million in the form of debt principal, debt interest, and tax payments.

Since the tax shield increases with the debt principal outstanding, Pure Gold wants to issue as much debt as it can without incurring costs of financial distress. Since Pure Gold does not need the cash raised through debt for investment, it pays it out to the shareholders as a dividend. Figure 3.6 plots firm value imposing the constraint that total debt and tax payments cannot exceed \$350 million. In this case, Pure Gold can always make its debt payments, so that we assume that there are no costs of financial distress. If the firm sells more debt, it is bankrupt. Consequently, if $F$ is the principal amount of the debt issued, it must be that:

$$\text{Debt principal} + \text{Debt interest} + \text{Taxes} = \$350M$$

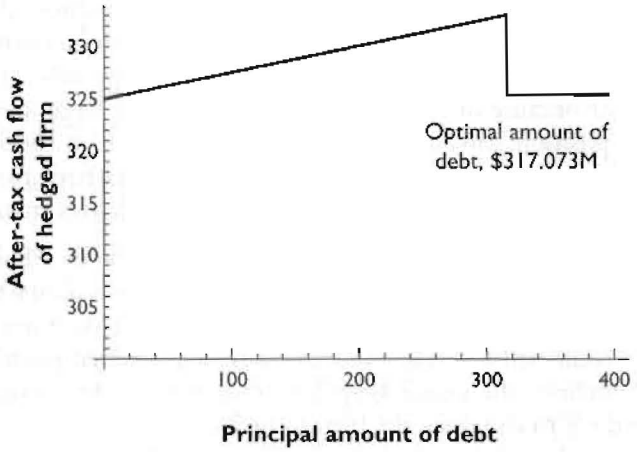
$$F + 0.05F + 0.5 \times (\$350M - \$300M - 0.05F) = \$350M$$

Solving for $F$, we get \$317.073 million. To see that this works, note that the firm has to pay taxes on income of $\$350M - \$300M - 0.05 \times \$317.073M$, corresponding to \$17.073 million. The debt payments are $\$317.073M + 0.05 \times \$317.073$, or \$332.927 million. The sum of debt payments and taxes is therefore exactly \$350 million.

By issuing more debt than F, Pure Gold would always be bankrupt as we have seen already. If it issued less debt instead, it could increase debt and make the shareholders better off. To see this, suppose the firm had \$1 million less of debt. Its dividend to shareholders would fall by \$1 million and it would have \$1.05 million less of debt payments at the end of the year. The decrease in debt payments would reduce the tax shield of debt by \$0.25 million, so that the shareholders would receive \$1.025 million at the end of the year instead of \$1 million

Firm after-tax cash flow and debt issue *Figure 3.6*

The firm has an expected pre-tax cash flow of $350 million. The tax rate is 0.5 and the risk-free rate is 5 percent. The figure shows the impact on after-tax cash flow of issuing more debt, assuming that the IRS disallows a deduction for interest of debt when the firm is highly likely to default.




today if the firm issued debt instead. The present value of $1.025 million is less than $1 million, so that shareholders are worse off.

In general, firms cannot eliminate all risk, so that debt is risky. By having more debt, firms increase their **tax shield from debt** but increase the present value of costs of financial distress. The **optimal capital structure** of a firm balances the tax benefits of debt against the costs of financial distress. A firm can reduce the present value of the costs of financial distress through risk management by making financial distress less likely. As a result, it can take on more debt. This is the case even if the firm cannot eliminate all risk as in the case of Pure Gold.

One complication we have ignored is that investors pay taxes too. Miller (1978) has emphasized that this complication can change the analysis. Suppose investors pay taxes on bond income but not on capital gains. In this case, they will want a higher return on debt than on equity to offset the high taxes. A higher yield would reduce the tax benefit of debt to the firm. The consensus among financial economists is that personal taxes may limit the corporate benefits from debt but not eliminate them. Whether there are personal taxes or not, the corporation will want to maximize the value of its tax shields.

### 3.3.2. Does Homestake have too little debt?

Homestake pays taxes every year. Most years, its tax rate is close to the statutory rate of 34 percent. In 1990, as we saw, Homestake paid taxes at a rate that exceeded the statutory rate. It has almost no debt, and its long-term debt is dwarfed by its cash balances. It surely has too little debt.

By increasing its debt, Homestake takes advantage of the tax shield of debt and reduces its taxes. An increase in debt similarly amplifies the importance of risk management.

## 3.4. Should the firm hedge to reduce the risk of large undiversified shareholders?

Investors who own well-diversified portfolios are relatively unaffected by firm-specific events. On average, their risks balance out, except for the systematic risks of the economy as a whole, which can be controlled by investors through their asset allocation. For other investors who have a large position in a firm, these risks do not balance out. Managers, for example, may have a large stake in the firm for control reasons or because of a compensation plan. Other large investors might value a control position. Investors who cannot diversify firm-specific risk care about the risks that the firm bears. They might want the firm to reduce risk, unless they can reduce it more cheaply through homemade risk management.

Suppose Pure Gold has only one large shareholder who holds 10 percent of the shares and nothing else. This undiversified shareholder cares about the diversifiable risk of the gold mining firm. She wants to reduce the risk of her investment. To do this, she could sell her stake and invest in a diversified portfolio and the risk-free asset. Second, she could keep her stake but use homemade hedging. Third, she could try to convince the firm to hedge.

The firm may have a comparative advantage in hedging and homemade hedging may not be possible for this large investor. Why should the firm expend resources to hedge to please that large investor? If the only benefit of hedging is that this large investor does not have to hedge on her own, the firm uses resources to hedge without increasing firm value. If the firm gains from having the large shareholder, however, then it can make sense to hedge to make it possible for the large shareholder to keep her investment in the firm.

### 3.4.1. Large undiversified shareholders can increase firm value

Large shareholders can increase firm value. Smaller and highly diversified shareholders have little reason to pay much attention to what a particular firm is doing. Their smaller stakes give them little benefit from evaluating carefully the actions of managers. A shareholder with a large undiversified stake in a firm will follow the actions of management carefully with an interest in increasing the value of the firm. Evaluating managers and trying to improve what they do is called monitoring management. Larger shareholders get greater financial benefits from monitoring management than smaller ones.

There are two reasons why shareholder monitoring can increase firm value. First, an investor might become a large shareholder because he has some ability in evaluating the actions of management in a particular firm. Such an investor has knowledge and skills that are valuable to the firm. If management chooses to maximize firm value, management welcomes such an investor and listens to him carefully.

Second, managers do not necessarily maximize firm value; they maximize their welfare like all economic agents. Doing so sometimes involves maximizing firm value. What a manager does depends on the incentives. If an action increases firm value but is very risky, a manager on a fixed salary may decide against it because a firm that is bankrupt cannot pay her salary. Monitoring can make it more likely that managers maximize firm value.

A large shareholder who finds that management failed to take an action that maximizes firm value might draw the attention of other shareholders to this fact. In some cases, a large shareholder may even convince another firm to attempt a takeover to remove management and take actions that maximize firm value.

A firm's risk generally makes it unattractive for a shareholder to have a stake large enough to make monitoring worthwhile. If it hedges, a firm may make ownership more attractive to a shareholder who has some advantage in monitoring management. As the large shareholder takes such a larger stake, all other shareholders benefit from the monitoring.

### 3.4.2. Risk and the incentives of managers

One way shareholders can ensure that managers are motivated to maximize the value of the company's shares is through a managerial compensation contract that gives managers a stake in how well the firm does. If managers earn more when the firm does better, this induces them to work harder. Managerial compensation related to the stock price also can have adverse implications for managers. In fact, making managerial compensation depend strongly on any part of the stock return that is not under control of management could be counterproductive. Suppose a firm has large stocks of raw materials that are required for production. In the absence of a risk management program, the value of these raw materials fluctuates over time. Random changes in the value of raw materials may be the main contributors to the volatility of a firm's stock price, yet managers have no control over the price of raw materials. Making managerial compensation depend strongly on the stock price in this case forces management to bear risks, but provides no incentive effects and does not align management's incentives with those of shareholders.

In general, it makes sense to tie managerial compensation to some measure of value created without trying to figure out what is and is not under management's control. If the firm can reduce its risk through hedging, firm value depends on variables that management controls; in this case, relating compensation to firm value does not force managers to bear too much risk and does not induce them to make decisions that are not in the interest of shareholders to eliminate this risk. When managers work hard to increase their compensation, they also work hard to increase shareholder wealth.

Ownership of shares in the firm ties managers' welfare more closely to shareholders' welfare. If they own shares, managers bear risk. Since managers are not diversified shareholders, they care about the firm's total risk. This may lead them to be conservative in their actions. To the degree risk is reduced through risk management, the total risk of the firm falls, and managers become more willing to take risks. Firmwide hedging thereby makes managerial stock ownership a more effective device to induce managers to maximize firm value.

A risk management program eliminates sources of fluctuation in market value due to forces that are not under management's control. This reduces the risk attached to management's human capital and makes it less likely that managers will undertake risk-reducing activities that diminish firm value. If the risk attached to management's human capital is lower, there may be a willingness to accept a lower compensation. Saving compensation enhances firm value.

Not every form of compensation that depends on firm value motivates management to reduce firm risk. Managerial compensation contracts that include call options on the firm's stock create incentives to take risks. To see how options might induce management not to hedge when hedging would maximize firm value, suppose Pure Gold's management owns a call option on 1,000 shares with exercise price of $350 per share. For simplicity, we assume that management received these options in the past and that exercise of the options does not affect firm value. Assuming a tax advantage to hedging, as we have discussed, firm value is maximized if the firm hedges. Hedging locks in a firm value before managerial compensation of $309.52. Management's options are worthless in this case. If the firm does not hedge, there is a 50 percent chance that the shares will be worth $375, which represents a 50 percent chance that the options will pay off. In this case, management chooses not to hedge even though shareholders would be better off otherwise.

### 3.4.3. Large shareholders, managerial incentives, and Homestake

The Homestake proxy statement for 1990 shows that the directors own 1.1 percent of the shares. Homestake's CEO, Harry Conger, owns 137,004 shares directly and has the right to acquire 243,542 shares through an option plan. The shares in the option plan have an average exercise price of $14.43, but the share price in 1990 never dropped below $15.30. Managers and directors hold few shares directly and less than is typical for a firm of that size; most of managers' ownership is in the form of options. There is not much incentive for management to protect its stake in the firm through hedging.

A large shareholder who monitors management might be able to increase firm value. To attract such a shareholder, the firm might have to commit to a risk management program. Yet it does not seem that management would want such an outcome. Homestake has one large shareholder, Case, Pomeroy and Co. This company owns 8.2 percent of the shares. Two executives of that company are on the board of directors. Case has been decreasing its stake in Homestake and has a standstill agreement with Homestake that prevents it from buying more shares and gives Homestake rights of first refusal when Case sells shares.

## 3.5. Stakeholders

Besides large undiversified shareholders, there are individuals and companies whose welfare depends on how well a firm is doing but who cannot diversify the impact of firm risks on their welfare. They can be workers, suppliers, or customers. Such individuals and firms are often called **stakeholders**. Does it make sense to reduce firmwide risk to reduce the risk borne by these individuals and companies?

### 3.5.1. When should firms care about stakeholders?

It is not unusual to hear that a firm should be managed for its stakeholders. In general, though, owners of the firm want the firm to be managed to make them better off, so that maximizing the welfare of stakeholders cannot be a legitimate corporate goal. Yet it is sometimes advantageous for shareholders to reduce the risks that stakeholders bear. Shareholders may want stakeholders to make long-term firm-specific investments. The firm, for instance, might want workers to

learn skills that would have minimal value outside the firm. Or it might want a supplier to devote R&D to design parts that only the firm will use. In another case, the value of a product customers buy depends on the firm's implicit warranty. In all these cases, the stakeholders will be reluctant to make firm-specific investments if they question the firm's financial health. If the firm gets in financial trouble, it may not be able to live up to its part of the bargain—that the stakeholders are investing in exchange for benefits from the firm over the long term.

Hedging makes it easier for the firm to honor its bargain with stakeholders. It can hedge at lower cost than the monetary compensation it would have to give to stakeholders to offset the impact on their welfare of the firm's risk. Without reducing risk, a firm may be able to get the stakeholders to make the requisite investments only by "bribing" them to do so. This means paying workers more so that they will learn the requisite skills, paying the suppliers directly to invest in R&D, and selling products more cheaply to compensate for the risks associated with the warranty. Such economic incentives are more expensive than hedging. Managing risk can therefore help the firm in getting others to make firm-specific investments and lower its costs of doing so.

### 3.5.2. Stakeholders and Homestake

Are stakeholders important for Homestake? Most likely, no. There is no reason to suspect that workers or suppliers have to make important firm-specific investments whose value would be seriously damaged if Homestake had financial difficulties. The welfare of Homestake's workers and suppliers depends on whether it makes sense to exploit Homestake's mines, not on whether Homestake is financially healthy. Should Homestake fail financially and file for bankruptcy, the new owners of the mine would still want to take advantage of the firm-specific investments made by workers and suppliers if it makes sense to extract gold from Homestake's mines.

A risk management program cannot make it profitable for Homestake to extract gold from its mines when otherwise it would not be. To understand this, suppose the price of gold falls to $150 per ounce, Homestake's extraction cost is $300, and Homestake hedged so that it sold gold forward for $350 per ounce. Rather than extract gold, Homestake is better off buying gold on the spot market to deliver on its forward contracts. It makes a profit of $200 per ounce this way. Producing gold, it only makes a profit of $50 per ounce.

Buyers of gold do not care about its provenance, so Homestake does not have to worry about relationships with customers.

## 3.6. Risk management, financial distress, and investment

So far, we have paid little attention to the fact that firms are ongoing entities that have opportunities to invest in valuable projects. Suppose Pure Gold has the opportunity to open a profitable new mine a year from now. A large investment must be made first. Without sufficient internal resources, the firm has to borrow or sell equity to finance the opening of the mine. If the costs of external financing are too high, Pure Gold might not be able to open the mine, and shareholders would lose the expected profits.

We investigate the main reasons why firms might not be able to invest in profitable projects because the cost of external financing is too high, and show how risk management can help avoid such situations.

### 3.6.1. Debt overhang

Too much debt induces shareholders to take on negative net present value projects and to avoid investing in valuable projects because they require issuing equity that dilutes their stake in the firm. When a firm has so much debt that it leads it to make investment decisions that benefit shareholders but affect its total value adversely, the firm has a **debt overhang**. As long as a firm has debt and risk, there is some possibility it may end up with a debt overhang. The probability that the firm might experience a debt overhang in the future reduces its value today. Consequently, risk management that reduces this probability increases firm value today.

A debt overhang can make shareholders take actions that reduce firm value but increase the value of the firm's equity. To see this, consider a firm, Highly Levered Gold (HLG). HLG never intended to have high leverage, but after successive mining disasters, it became highly levered because losses ate away at its equity. Suppose that the financial situation of HLG is such that if firm value does not increase sharply before the maturity of its debt, shareholders will receive nothing and the creditors will own the firm. Suppose further that if shareholders do nothing, HLG's value cannot increase sufficiently to enable it to repay its creditors. To make it more likely that firm value will increase sufficiently to make their shares valuable, shareholders can increase HLG's risk. If they take projects that have some chance of a large payoff but otherwise lose money, shareholders make money if the projects do well but do not lose money if the projects do poorly since they would have received nothing anyway. In fact, shareholders will be willing to take these long-shot projects even if they have a negative net present value.

When a firm has a large debt overhang, its shareholders may decide against raising funds to finance valuable new projects. Suppose that HLG has a valuable investment opportunity: By investing $10 million, the firm acquires a project that has a positive net present value of $5 million. The project is small enough that it will not enable HLG to repay its debt. The firm has no cash. The only way it can invest is by raising funds.

Borrowing is not an option. Consequently, HLG would have to sell equity to raise funds. Consider the impact of having an investor invest one dollar in new equity. The investor will only invest the dollar if she can expect to earn an appropriate return given the risk she takes. If an investor invests one dollar in a new share, that money most likely will end up in the pockets of the creditors since the most likely outcome is that the firm will not have money left after paying the creditors. This extra dollar will be a windfall for the creditors. Since the creditors will receive that dollar without having to pay for it, the old shareholders will have to pay for it through a reduction in the value of their stake brought about by the fact that they have to share the equity payoffs with the new investor. Hence, even though the project would increase firm value, the current shareholders will not want the firm to take it because it will not benefit them. The only way the firm would take the project is for shareholders to renegotiate with creditors so that they get more of the payoff of the project. Such a renegotiation is difficult and costly, and sometimes, no such renegotiation succeeds.

To understand why the debt overhang leads to underinvestment, let's look at a simple example. Suppose HLG can sell one million ounces of gold at either \$450 or \$250 at the end of the year. Each outcome has a probability of 0.5. Gold price risk is not systematic risk. HLG has debt payments of \$400 million. The value of the debt is therefore [(0.5 × \$250M) + (0.5 × \$400M)]/1.05, or \$309.524 million. The value of equity is 0.5 × \$50M/1.05, or \$23.8095 million. Now, HLG receives an investment opportunity that pays \$10 million for sure but costs \$5 million. It has to raise \$5 million to finance the investment opportunity.

Firm value without the investment opportunity is \$350M/1.05, or \$333.33 million. With the investment opportunity, it is \$360M/1.05, or \$342.857 million. Taking the investment opportunity increases firm value, but who benefits from the investment opportunity? If the gold price is \$250, the bondholders get all the benefit of the funds raised—they get \$10 million more. If the gold price is \$450, the shareholders get all the benefit of the funds raised. The value of equity therefore increases by 0.5 × 10M/1.05, or \$4.7619 million. The shareholders raise \$5 million, but equity increases by less. Since the new shareholders must receive \$5 million worth of claims against the firm, the value of the claims of the old shareholders must fall from \$23.8095 million to \$23.5714 million. The share price must fall as the firm takes advantage of the new investment opportunity even though firm value increases. The old shareholders therefore prefer that the firm does not raise funds and does not invest in the investment opportunity. The firm therefore underinvests—it does not invest in a project that is a positive net present value project for the firm.

The value of a firm in the capital markets is lower when there is a probability that it may not enter into valuable projects because its financial health might be poor. Reducing this probability through risk management increases firm value as long as risk management is cheap enough.

### 3.6.2. Information asymmetries and agency costs of managerial discretion

The key problem management faces in raising funds is that managers know more about the firm's projects than the outsiders they are dealing with. When one party to a deal knows more than the other, we call this an **information asymmetry**. Suppose that the firm's equity with its current projects is \$100 million. Managers believe that by raising \$100 million of new equity and investing the proceeds, they can invest in a project with a net present value of \$50 million. If they ask you to invest, you have to figure out the return on your investment based on the information provided to you by management.

Generally, managers benefit from firm growth, so that they have much to gain by undertaking new projects, which can lead to biases. They may tend to minimize problems. Even if they are completely unbiased and reveal all the information they have to potential investors, you as an investor cannot easily tell that. Often, management has enough to gain from undertaking a project that it might want to invest even if the chance of success is low enough that the project is a negative net present value project.

The costs associated with management's opportunity to undertake projects that have a negative net present value when it is advantageous for them to do so are called **agency costs of managerial discretion**. When managers have

discretion to take actions, they can pursue their own objectives, which creates agency costs. That is, the agent's interests, or management's interests, are not aligned with the interests of the principals who hire management, namely, the shareholders.

Agency costs of managerial discretion make it harder for a firm to raise funds and increase the cost of funds. If outsiders are not sure that the project is as likely to pay off as management claims, they want more compensation for providing the funds. Even if the project is as described, having to pay a higher expected compensation reduces the profits from the project. The project may not be profitable because the cost of capital for the firm is too high.

There is more than one way to reduce the costs of managerial discretion and hence reduce the costs of the funds raised. A firm could entice a large shareholder to come on board. This shareholder would see the company from the inside, and would be better able to assess whether the project is valuable. Or a risk management strategy might preserve ongoing firm value and hence might enable the firm to take the project. A firm whose value is not in doubt may be able to borrow against assets rather than try to borrow against the future project.

A risk management strategy that preserves firm value might help the firm to finance the project for another reason. Investors who look at a firm's history have to figure out what a loss in firm value implies. In general, it will be difficult for outsiders to see exactly what is going on. They will therefore always worry that the true explanation for the losses is incompetent management. There could be many explanations for a loss in firm value. Firm value could fall because a stock of raw materials fell in value, because the economy is in a recession, because a plant burned down, or because management is incompetent. Outsiders cannot be sure. If it reduces risk through risk management, the firm makes it easier for investors to assess the ability of management since it eliminates some sources of unexpected losses.

### 3.6.3. The cost of external funding and Homestake

Is it really the case that external funding can be more expensive than internal funding? The answer is yes. There is much empirical evidence that shows that firms with poor cash flow have to cut back investment. The problem with that evidence is that poor cash flow might signal bad investment opportunities, in which case it would not be surprising to see that firms with poor cash flow cut investment. However, this is not the whole story. Lamont (1997) shows that drops in oil prices led oil companies to cut back investment in their non-oil activities. An oil company that sees its cash flow drop has no reason to reduce investment in the department stores it owns unless external financing is more costly than internal financing, so that when the firm has to switch from internal financing to outside financing, the cost of capital increases and some investments are no longer worthwhile.

Box 3.1, Warren Buffett and Catastrophe Insurance, provides an example where an insurance product is priced in a way that can be explained only by the existence of steep costs of external finance because of agency costs. The example also shows that the agency costs and information asymmetries discussed in this section can make risk management products more expensive.

## Warren Buffett and Catastrophe Insurance *Box 3.1*

Insurance companies hedge some of their exposure to catastrophes such as earthquakes, hurricanes, or tornadoes by insuring themselves with reinsurers. A typical reinsurance contract promises to reimburse an insurance company for claims due to a catastrophe within some range. For example, an insurance company could be reimbursed for up to $1 billion of California earthquake claims in excess of $2 billion. Catastrophe insurance risks are diversifiable risks, so bearing these risks should not earn a risk premium. This means that the price of the insurance should be the expected losses discounted at the risk-free rate. Yet, in practice, the pricing of reinsurance does not work this way.

Let's look at an example. In the fall of 1996, Berkshire Hathaway, Warren Buffett's company, sold reinsurance to the California Earthquake Authority in the amount of $1.05 billion insured for four years. The annual premium was 10.75 percent of the annual limit, or $113 million. The probability that the reinsurance would be triggered was estimated at 1.7 percent at inception by EQE International, a catastrophe risk modeling firm. Ignoring discounting, the annual premium was therefore 530 percent of the expected loss (0.1075 is 530 percent of 0.017). If the capital asset pricing model had been used to price the reinsurance contract, the premium would have been $17.85 million in the absence of discounting and somewhat less with discounting.

How can we make sense of this huge difference between the actual premium and the premium predicted by the capital asset pricing model? A reinsurance contract is useless if there is credit risk; that is, the reinsurer has to have liquid assets that enable it to pay the claims. The problem is that holding liquid assets creates managerial discretion agency costs. It is difficult to ensure that a reinsurer will indeed have the money when needed. Once the catastrophe has occurred, the underinvestment problem would prevent the reinsurer from raising the funds because the benefit from raising the funds would accrue to the policyholders rather than to the investors. The reinsurer therefore has to raise funds when the policy is agreed upon. Hence, in the case of this example, the reinsurer would need, if it did not have the capital, to raise $1.05 billion minus the premium.

The investors have to be convinced that the reinsurer will not take the money and run or take the money and invest it in risky securities. Yet the reinsurer has strong incentives to take risks unless its reputational capital is extremely valuable. In the absence of valuable reputational capital, the reinsurer can gamble with the investors' money. If the reinsurer wins, it makes an additional profit. If it loses, the investors or the insurer's clients lose.

Another problem with reinsurance is due to information asymmetries and agency costs in the investment industry. The reinsurer has to raise money from investors, but the funds provided would be lost if a catastrophe occurs. Most investment takes place through money managers who act as agents for individual investors. In the case of funds raised by reinsurance companies, the money manager is in a difficult position. Suppose that he decides that investing with a reinsurance firm is a superb investment. How can the individual

*(continued)*

**Box 3.1 (continued)**

investors who hire the money manager know that he has acted in their interest if a catastrophe occurs? They will have a difficult time deciding whether the money manager was right and they were unlucky or the money manager was wrong. This problem leads the money manager to require ample compensation for investing with the reinsurance firm.

Berkshire Hathaway has reputational capital that makes it unprofitable to gamble with investors' money. Consequently, it does not have to write a complicated contract to ensure that there will not be credit risk. Since it has already large reserves, it does not have to deal with the problems of raising large amounts of funds for reinsurance purpose. Could these advantages be worth as much as it seems in the great difference between the California premium and the theoretical price? There is no evidence that there were credible reinsurers willing to enter cheaper contracts. With perfect markets, such reinsurers would have been too numerous to count.

**Source:** Kenneth Froot, "The limited financing of catastrophe risk: An overview," *The Financing of Property Casualty Risks*, University of Chicago Press, 1997.

Homestake could repay all its debt with its cash reserves, so that debt overhang is not an immediate issue. The firm also has enough cash that it could finance large investments out of internal resources. Yet if gold prices fell, Homestake's resources would shrink over time. At some point, its ability to undertake new projects might be compromised. When gold prices are low, Homestake might have few good investment opportunities. However, if it expects to have more valuable investment opportunities if gold prices fall, it might want to put in place a risk management program that insures that it will have appropriate financial resources to finance these investment opportunities.

## 3.7. Summary

In this chapter, we have investigated ways that firms without risk management can leave money on the table. They can:

1. Bear more bankruptcy costs and financial distress costs than they should.
2. Pay more taxes than they should.
3. Have less leverage than they should.
4. Have managers provided with poor incentives.
5. Fail to retain valuable large shareholders.
6. Fail to get stakeholders to make firm-specific investments.
7. Find it unprofitable to invest in positive net present value projects.
8. Find it profitable to take bad projects.

We have identified benefits from risk management that can increase firm value. In the next chapter, we move on to the question of whether and how such benefits can provide the basis for the design of a risk management program.

## Key Concepts

agency costs of managerial discretion, 71
bankruptcy costs, 55
costs of financial distress, 58
deadweight costs, 53
debt overhang, 70
information asymmetry, 71
optimal capital structure, 65
stakeholders, 68
tax shield from debt, 65

## Review Questions

1. How does risk management affect the present value of bankruptcy costs?
2. Why do the tax benefits of risk management depend on the firm having a tax rate that depends on cash flow?
3. How do carrybacks and carryforwards affect the tax benefits of risk management?
4. How does risk management affect the tax shield of debt?
5. Does risk management affect the optimal capital structure of a firm? Why?
6. Does it pay to reduce firm risk because a large shareholder wants the firm to do so?
7. How does the impact of risk management on managerial incentives depend on the nature of management's compensation contract?
8. Is risk management profitable for the shareholders of a firm that has a debt overhang?
9. How do costs of external funding affect the benefits of risk management?

## Literature Note

Smith and Stulz (1985) provide an analysis of the determinants of hedging policies that covers the issues of bankruptcy costs, costs of financial distress, stakeholders, and managerial compensation. Diamond (1981) shows how hedging makes it possible for investors to evaluate managerial performance more effectively. DeMarzo and Duffie (1991) and Breeden and Viswanathan (1998) show that hedging is valuable because of information asymmetries between managers and investors. Froot, Scharfstein, and Stein (1993) derive explicit hedging policies when firms would have to invest suboptimally in the absence of hedging because of difficulties in securing funds to finance investment. Stulz (1990, 1996) discusses how hedging can enable firms to have higher leverage. Stulz (1990) focuses on the agency costs of managerial discretion. Hedging makes it less likely that the firm will not be able to invest in valuable projects, so it can support higher leverage. One reason debt is valuable is because it prevents managers from

making bad investments. Tufano (1998) makes the point that reducing the need to go to the external capital markets also enables managers to avoid the scrutiny of the market. This will be the case if greater hedging is not accompanied by greater leverage. Myers (1977) was the first one to provide an analysis of debt overhang, showing how it can lead shareholders to be unwilling to raise funds for valuable new projects. The empirical evidence on the positive relation between investment and cash flow is discussed in Hubbard (1998). Bessembinder (1991) and Mayers and Smith (1987) analyze how hedging can reduce the underinvestment problem. Leland (1998) provides a model where hedging increases firm value because (1) it increases the tax benefits from debt and (2) it reduces the probability of default and the probability of incurring distress costs. Ross (1997) also models the tax benefits of hedging. Petersen and Thiagarajan (1998) provide a detailed comparison of how hedging theories apply to Homestake and American Barrick.

# Chapter 4

## A Firm-Wide Approach to Risk Management

### Chapter 4 Objectives

At the end of this chapter, you will:

1. Understand how to choose a risk measure.
2. Know how to measure value at risk (VaR) and cash flow at risk (CaR).
3. Be able to use VaR and CaR to make investment decisions.
4. Know how to manage risk when risk is measured by VaR or CaR.

Early in the 1990s, the CEO of JP Morgan, Dennis Weatherstone, wanted to know the bank's risk at the end of the trading day. He asked his staff to devise a risk measure that would yield one number that could be communicated to him at 4:15 PM each trading day and would give him an accurate view of the bank's risk. He wanted to have a sense of the risk of bad outcomes that would create problems for the bank. In Chapter 2, we considered three risk measures: volatility, systematic risk, and unsystematic risk. None of these measures provides a direct answer to the question Weatherstone wanted answered because none of them specifically measures downside risk. The risk measure that Weatherstone eventually received from his staff was an estimate of the bank's trading portfolio **value at risk (VaR)**, defined as the loss in value of the portfolio that has a 5 percent probability of being exceeded the next day.

Chapter 3 showed that there are five major reasons why risk management can increase shareholder wealth. These reasons are:

1. Risk management can reduce the present value of bankruptcy and financial distress costs.
2. It can make it more likely that the firm will be able to take advantage of valuable investment opportunities.
3. It can reduce the present value of taxes paid by the corporation.
4. It can increase the firm's debt capacity.
5. It reduces the cost to stakeholders, large shareholders, and managers of bearing firm-specific risk.

In general, these benefits from risk management come from the fact that bad outcomes for firms have knock-on effects or deadweight costs. A gold mining firm faced with lower gold prices can lose more than just the loss in immediate sales revenue. As a result of low gold prices, it may not be able to invest in profitable projects. It is therefore important to be able to quantify downside risk—the risk of bad outcomes. VaR is such a measure of downside risk.

Chapter 3 provides us with a catalog of benefits from risk management. Though such a catalog is an important starting point in understanding risk management, it is only the first step. For risk management to be used to maximize firm value, one must concretely define how risk is measured and how it is managed. A bad outcome for an individual investment might be offset by a good outcome for another investment and therefore have no deadweight costs, while a bad outcome for the firm as a whole will have deadweight costs. Consequently, the risk that has to be measured and managed is firm-wide risk. This chapter presents a framework that makes it possible to do that.

In the first part of the chapter, we show how the benefits of risk management presented in Chapter 3 lead to the choice of a risk measure. For some firms, that risk measure is VaR. The choice of a risk measure depends on the characteristics of the firm. Armed with a risk measure, a firm can evaluate the impact of new projects on its risk and assess the profitability of existing and new activities. Having specified the choice of a risk measure, we then discuss the tools available for risk management. Firms can manage their cost of total risk through equity,

through their choice of projects, or through transactions in financial markets. Different tools have different costs and benefits. Derivatives are generally the most cost effective tool to manage firm risk.

## 4.1. Measuring risk for corporations

To understand the considerations that affect a firm's choice of a risk measure, we look at two concrete examples that demonstrate the trade-offs involved in choosing risk measures: first, financial firms, and second, nonfinancial corporations.

### 4.1.1. Measuring value at risk in a financial firm

A financial firm's ability to conduct business depends on its creditworthiness. Financial firms generally have customers who are also creditors. A depositor in effect lends his money to a bank. A firm that enters into a derivatives contract with an investment bank is a creditor if it expects to receive a payment from the bank at maturity. The buyer of a life insurance policy is a creditor of the insurance company. Customers of any financial firm are extremely sensitive to its credit risk because they cannot diversify this risk and often cannot hedge it.

Customers of financial firms have a dramatically different attitude toward credit risk from investors in capital markets. Even if you are willing to hold risky bonds as part of a diversified portfolio, you generally want your checking account to have no risk. A check is a substitute for cash. If your checking account is subject to significant credit risk, a check for $100 could be worth less than $100. Each transaction made using a check drawn on the checking account would require a negotiation to determine the appropriate compensation for credit risk paid to the seller.

Similarly, a firm that enters a forward contract with a financial firm wants the forward contract to serve as an effective hedge. If the financial firm has substantial credit risk, it might not deliver on the forward contract. This possibility makes the forward contract less useful as a hedging device. Finally, no policyholder would be willing to pay half as much for a life insurance contract that has a 0.5 probability of paying off because of credit risk.

An increase in the probability of default risk can have a dramatic impact on a financial firm's business. As default risk becomes significant, customers withdraw their money, the derivatives business dries up, and the life insurance business disappears. Shareholder wealth in a financial firm is fragile, probably more so than at any other type of corporation.

Because customers are creditors in financial firms, financial firms are highly leveraged. The more business a financial firm has for a given amount of capital, the greater its leverage. An adverse shock to a financial firm can cause its equity to disappear quickly as customers react to the shock by withdrawing their business. Costs of financial distress are significant for financial firms because often the mere hint of financial distress can create a run on the firm that eliminates its value as an ongoing business.

A financial firm must control its risks with extreme care. It must make sure there is little probability that it will lose customers because of credit risk. Its risk

management effort must focus on computing, monitoring, and managing a measure of risk that corresponds to the probability that it will lose customers because of credit risk.

What type of event would make a bank risky for its customers? Its assets are loans and securities; its liabilities are deposits and debt. Some assets, securities, are often marked to market; other assets and liabilities are typically kept at book value. Marked to market means that values on the balance sheet are market values. Changes in the value of assets marked to market represent a gain or loss for the bank that impacts earnings, the value of equity, and regulatory capital. If the net value of the securities held by the bank falls sharply, the bank may have difficulties meeting its obligations. Banks also typically have derivatives positions that could require them to make large payments in the future. We can think of all positions in traded securities and derivatives as the bank's portfolio of traded financial instruments.

As long as the bank has risky traded financial instruments and is leveraged, it cannot be completely safe. Any event that exposes the bank to losses in its portfolio above a critical size is dangerous. The bank must keep the probability of losses above a critical size from traded financial instruments low. To manage its risk, the bank has to specify both this critical loss size and the acceptable probability that this loss size will be exceeded.

Let's consider Trading Bank Inc., or TB. Say TB decides that it wants the probability of a loss exceeding 10 percent of the value of its traded financial instruments over one day to be lower than 5 percent. That is, 95 percent of the time, the return of the portfolio must be higher than −10 percent. To compute this probability, TB has to know the distribution of the gains and the losses of the portfolio.

Let's assume that the return of the portfolio is normally distributed. The expected return is 10 percent and the volatility is 20 percent. We can use the analysis in Chapter 2 to find the probability that the portfolio will incur a loss exceeding 10 percent over one day. The probability that the return will be lower than some number $x$ over a day, Prob[Return < $x$], is given by the cumulative normal distribution function evaluated at $x$.

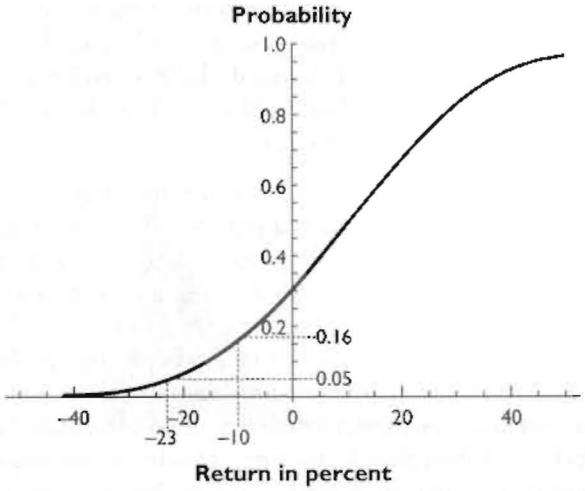
Figure 4.1 shows how we can use the cumulative normal distribution to find the probability that the portfolio will incur a loss of at least 10 percent over one day. We pick the return of −10 percent on the horizontal axis and read the probability on the vertical axis corresponding to the level of the cumulative normal probability distribution, which is 16 percent. Or, by looking at the probability equal to 5 percent on the vertical axis, we can get on the horizontal axis that the firm has a 5 percent probability of losing at least 23 percent. If the return on TB's portfolio of traded financial instruments is distributed normally, once we know the volatility of the return and the expected return, we have all the information we need to compute any statistic for the distribution of gains and losses.

Suppose that TB follows this approach. It has a portfolio of traded financial instruments worth $2 billion, so a 10 percent loss is equal to $200 million. TB does the numbers, and finds that it has a 5 percent probability of incurring a loss of at least 23 percent, or $460 million. If TB had decided that it could only afford to

## Using the cumulative distribution function

*Figure 4.1*

The figure graphs the cumulative distribution function of a normally distributed return with expected value of 10 percent and volatility of 20 percent. From this graph, the probability of a loss of 23 percent or greater is 0.05.




have a loss of $200 million or more with a probability of 5 percent, it has too much risk. What can TB do to reduce its risk? It can sell risky financial instruments and put the proceeds in risk-free assets. Or it can hedge more, if appropriate hedging instruments are available. The risk measure lets TB decide how to manage the risk of its portfolio of traded financial instruments, so that its customers do not worry about being exposed to significant credit risk.

The dollar loss that will be exceeded with a given probability over some given measurement period is called *value at risk* or *VaR*. VaR can be computed for a firm, a portfolio, or a trading position. The $z^{th}$ quantile of a distribution is a number such that there is a probability of $z$ percent that the random variable is below that number and $(100 - z)$ percent that it is above. The VaR at the probability level of $z$ percent is the loss corresponding to the $z^{th}$ quantile of the cumulative probability distribution of the value change at the end of the measurement period. VaR at the probability level of $z$ percent is the dollar loss that has a probability $z$ percent of being exceeded over the measurement period. Formally, VaR is the number such that Prob[Loss > VaR] = $z$ percent.

Note that this definition makes no assumption about the distribution function of the loss. Throughout the book, we will use $z$ percent as 5 percent unless we specify otherwise. If VaR is a loss that is exceeded with probability of $z$ percent, there is a $(100 - z)$ percent probability that the loss will not be exceeded. We can therefore consider an interval from minus VaR to plus infinity such that the probability of the firm's gain belonging to that interval is $(100 - z)$ percent. In statistics, an interval constructed this way is called a one-sided confidence interval. One can also think of VaR as the maximum loss in the $(100 - z)$ percent confidence interval, or in short, the maximum loss at the $(100 - z)$ percent confidence level. If we compute the VaR at the 5 percent probability level, it is therefore also

the maximum loss at the 95 percent confidence level. We are 95 percent sure that the firm's gain will be in the interval from minus VaR to plus infinity.

In Chapter 2, we considered three risk measures. These measures were volatility, systematic risk, and nonsystematic risk. None of these measures provides a measure of the risk of bad outcomes, and so none of these measures would have provided the information about the riskiness of JP Morgan that Dennis Weatherstone wanted each day at 4:15 PM. In general, there is no direct relation between VaR and these three risk measures. (You will see in this chapter that the normal distribution is an exception to this statement.)

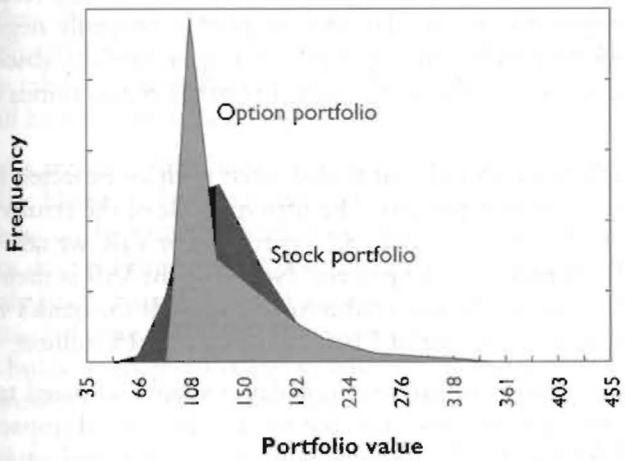
With many types of securities, it is possible for volatility to increase and VaR to fall at the same time, which may seem a paradox. The following is an example for why volatility can increase and the corporation can be better off, so that volatility is an inappropriate risk measure. Suppose a corporation has the opportunity to receive a free lottery ticket that pays off in one year. This ticket has a small chance of an extremely large payoff. Otherwise, it pays nothing. If the firm accepts the free lottery ticket, its one-year volatility will be higher, because the value of the firm now has a positive probability of an extremely large payoff that it did not have before. A firm that focuses on volatility as its risk measure would therefore conclude that taking the lottery ticket makes it worse off if the volatility increase is high enough. Yet there is no sense in which the firm can be made worse off by receiving something for free that can have only positive value. Shareholders would always want management to take the lottery ticket, so under some circumstances they will want management to increase firm volatility. The firm's VaR would not be increased if the firm accepts the free lottery ticket.

Figure 4.2 shows an illustration of how return volatility can fail to convey the information that Dennis Weatherstone wanted. We show the return frequency distribution for two different portfolios. These two portfolios are constructed to have the same return volatility of 30 percent. One portfolio holds $100 million of a common stock and has normally distributed returns. The other portfolio holds $76.89 million in the risk-free asset and call options on 1.57 million shares of the same common stock as the first portfolio with exercise price per share equal to the current stock price and maturity in one year. The portfolio with options does not have normally distributed returns. While the two portfolios have the same return volatility, the portfolio with options has a very different VaR from the portfolio without options. The stock portfolio has a one-year 5 percent VaR of $41.93 million, while the portfolio holding the risk-free asset and options has a one-year 5 percent VaR of $15 million (we cover calculation of the VaR of portfolios with options in Chapter 13).

The reason volatility is not useful to evaluate the risk of bad outcomes is because the portfolios have very different worst-case returns. The worst returns of the portfolio with options are much less negative than the worst returns of the stock portfolio because the portfolio with options has no stock exposure when the stock has poor returns. Bad returns for the stock portfolio might bankrupt the bank, but bad returns for the portfolio with options might not. Beta and unsystematic risk cannot help us understand the distribution of bad outcomes either. Since both the risk-free asset and a volatile stock can have a beta of zero, beta is not helpful in understanding downside risk. If the stock in the two portfolios we just considered has a beta of zero, the volatility of the return of the portfolios is

Frequency distribution of two portfolios over a one-year horizon *Figure 4.2*

The stock portfolio is invested in a stock that has an expected return of 15 percent and a volatility of return of 30 percent over the measurement period. The other portfolio has calls on 1.57 million shares of the stock with exercise price of $100 per share that cost $23.11 million and the rest invested in the risk-free asset earning 6 percent.




unsystematic risk, but in this case the portfolio with the greater unsystematic risk has less downside risk. Hence, unsystematic risk is not useful to measure downside risk. Had JP Morgan's staff provided Dennis Weatherstone with the systematic risk of the bank or its unsystematic risk, he would not have received an appropriate answer to his question.

The plots in Figure 4.2 indicate we need to understand the distribution of the returns of the bank's positions to compute its VaR. To answer Dennis Weatherstone's question, his staff had to know the value of all the marked-to-market positions of the bank at the end of the trading day and had to have a forecast of the joint distribution of the returns of the various securities held by the bank. As we will see in later chapters, forecasting the distribution of returns and computing VaR can be challenging when securities are complex.

Computing the VaR is straightforward, though, when the returns are normally distributed. A random variable follows the standard normal distribution when it is normally distributed, has an expected value of zero, and a volatility equal to one. The probability that a random variable following the standard normal distribution takes a value lower than −1.65 is 5 percent. The fifth quantile of the standard normal distribution is therefore −1.65. Any normally distributed random variable can be transformed into a random variable that follows the standard normal distribution by subtracting the mean from the random variable and dividing the resulting variable by the volatility of the random variable. If $z$ is a normally distributed random variable, $u = [z - E(z)]/[\mathrm{Vol}(z)]$ follows the standard normal distribution because it has mean zero and volatility equal to one. Consequently, the fifth quantile of the distribution of $z$ can be obtained from the fifth

quantile of $u$ since $-1.65$ = Fifth quantile of $[z - E(z)]/[\text{Vol}(z)]$. Using this result, we have a formula for the fifth quantile of $z$:

$$\text{Fifth quantile of } z = -1.65 \times \text{Vol}(z) + E(z)$$

Hence, if the return of a portfolio is distributed normally, the fifth quantile of the return distribution is the expected return minus 1.65 times the return volatility. For changes computed over one day, this number is generally negative. VaR is the loss corresponding to the fifth quantile. It is therefore the absolute value of this negative change, or 1.65 times the volatility of the return minus the expected return.

Suppose a bank has a portfolio of traded assets with an expected return of 0.1 percent and a volatility of 5 percent. The fifth quantile of the return distribution is 0.1 percent – 1.65 × 5 percent, or –8.15 percent. For VaR, we take the absolute value of the fifth quantile, or 8.15 percent. Note that the VaR is then simply 1.65 times the volatility minus the expected return. Hence, if the bank's value is $100 million, the VaR is 8.15 percent of $100 million, or $8.15 million.

In general, the expected return over one day is small compared to the volatility. This means that ignoring the expected return has a trivial impact on an estimate of the VaR for one day. In practice, therefore, the expected return is ignored. With normally distributed returns and zero expected change, the formula for VaR is:

**Formula for VaR when returns are distributed normally and expected return can be ignored**

If the portfolio return is normally distributed, has zero mean, and has volatility $\sigma$ over the measurement period, the 5 percent VaR of the portfolio is:

$$\text{VaR} = 1.65 \times \sigma \times \text{Portfolio value}$$

The VaR in the example would then be 1.65 × 5% × $100M, or $8.25 million.

In this case, there is a direct relation between volatility and VaR; VaR increases directly with volatility. In general, however, as shown in Figure 4.2, portfolios with the same return volatilities can have different VaRs, and portfolios with the same VaRs can have different volatilities.

An important issue is the time period over which the VaR should be computed. Remember that a financial firm wants to monitor and manage the size of potential losses so that the probability of financial distress is not too large. If a bank can measure its risk and change it once a day, the one-day VaR is useful to control risk over time. At the end of a day, managers decide whether the VaR for the next day is acceptable. If it is not, they take actions to change that risk. If it is acceptable, they do nothing. At the end of the next day, they go through the process again. However, if the bank is stuck with its portfolio for a number of days because the markets for the securities it holds are illiquid, then the one-day VaR is not relevant because it does not measure a risk the bank can manage. In this case, the bank would have to measure VaR over a period over which it could change its portfolio.

The bank will care about its risk over longer horizons. For example, it will worry about the impact of adverse earnings on its regulatory capital. Controlling the one-day VaR throughout the year will help in averting earnings shortfalls. However, the bank will also have to measure risk at longer horizons. It is not clear how one would compute a one-year VaR for a trading portfolio and what it would mean for a bank. The bank could compute a one-year VaR, assuming that the VaR over the next day will be maintained for a year, but the number would be meaningless. The bank's risk changes on a daily basis as trades are made. Further, if the financial firm incurs large losses or if its risk increases too much, it will immediately take steps to reduce its risk. When computing its risk over one year, the bank will have to take into account the policies it implements to manage risk.

Credit risks are generally a substantial source of risk for banks because of their loan portfolio. However, banks do not have the information to compute changes in the riskiness of their loan portfolio on a daily basis. Loans are not marked to market every day and firms release accounting data that might be useful at most on a quarterly basis. This means that a bank typically estimates credit risks over a different period of time than it measures risks associated with the market value of securities it holds (market risks). As we will see in Chapter 18, however, VaR can be used to measure the risk of a portfolio of loans.

VaR plays an important role in financial firms not only as a risk management tool, but also as a regulatory device. Box 4.1, VaR, banks, and regulators, shows that large banks can use VaR to compute their regulatory capital.

## VaR, banks, and regulators — Box 4.1

The U.S. regulatory agencies adopted the market risk amendment to the 1988 Basle Capital Accord, which regulates capital requirements for banks to cover credit risk, in August 1996. This amendment became effective in January 1998. It requires banks with significant trading activities to set aside capital to cover market risk exposure in their trading accounts.

The central component of the regulation is a VaR calculation.The VaR is computed at the 1 percent level for a ten-day (two-week) holding period using the bank's own model. The capital the firm must set aside depends on this VaR in the following way. Let $VaR_t(1\%,10)$ be the VaR of the trading accounts computed at the 1 percent level for a ten-day trading period at date $t$. The amount of capital the bank has to hold for the market risk of its trading accounts is given by:

$$\textbf{Required capital for day } t+1 = \mathrm{Max}\left[\mathrm{VaR}_t(1\%,10);\ S_t \times \frac{1}{60}\sum_{i=1}^{59}\mathrm{VaR}_{t-i}(1\%,10)\right] + \mathrm{SR}_t$$

where $S_t$ is a multiplier and $SR_t$ is an additional charge for idiosyncratic risk. The terms in square brackets are the current VaR estimate and an average of

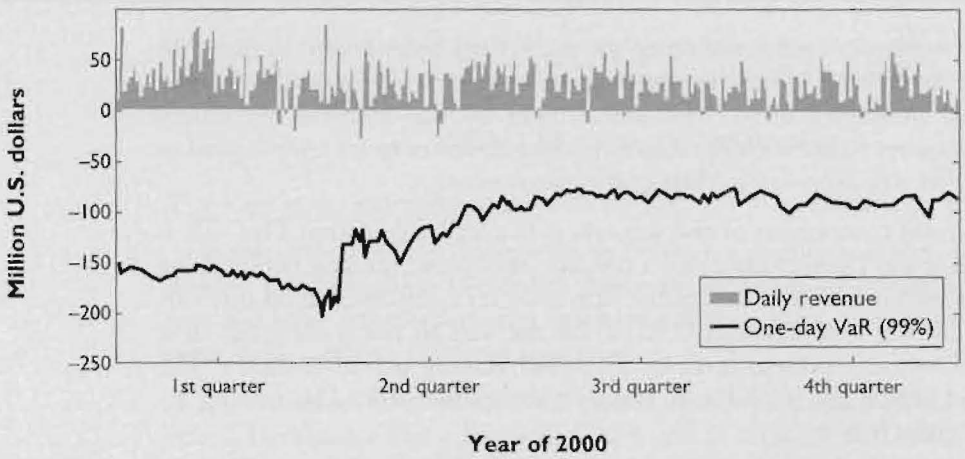
(continued)

## Box 4.1 (continued)

the VaR estimate over the last 60 days. The multiplier $S_t$ depends on the accuracy of the bank's VaR model. The multiplier is determined by back testing the bank's VaR for a one-day period at the 1 percent level over the last 250 days. If the bank exceeds its daily VaR four times or less, it is in the green zone and the multiplier is set at 3. If the bank exceeds its daily VaR five to nine times, it is in the yellow zone and the multiplier increases with the number of cases where it exceeds the VaR. If the bank exceeds its daily VaR ten times or more, its VaR model is deemed inaccurate and the multiplier takes a value of 4. Hence, by having a better VaR model, the bank saves on regulatory capital.

Banks routinely provide information on their VaR in their annual reports. The accompanying illustration shows the daily trading revenue and the daily VaR of Credit Suisse First Boston in 2000. As we can see, this illustration shows that the VaR was never exceeded during that year. The VaR is computed on a ten-day horizon at the 99 percent confidence level using two years of historical data. The illustration scales down the ten-day VaR to a one-day VaR. It is surprising that in this firm the VaR estimates are so much lower than the worst trading outcomes. Research by Berkovitz and O'Brien (2001) shows that the models that banks use for regulatory reporting tend to be extremely conservative.

*Illustration* The trading revenue of Credit Suisse First Boston in 2000




Financial firms have other risks besides market and credit risks. Someone might make a mistake in a specific transaction. A standardized contract might include a clause that turns out to be invalid and its discovery could create large losses. A trader might find a chink in the accounting software of the bank that allows him to hide losses in a trading position. Top management might make a bad strategic decision. These are operational risks. Risk managers are only starting to find useful ways to quantify such risks.

### 4.1.2. Implementing VaR

How did the staff of JP Morgan come up with a VaR estimate? The details of the procedure used within the bank are not available. However, JP Morgan made publicly available in 1994 a method to estimate VaR that is closely related to the method used internally. The approach is called RiskMetrics™. Eventually, JP Morgan formed a company called RiskMetrics that provides risk management consulting based on the approach developed within the bank.

To estimate VaR, one has to forecast the fifth percentile of the distribution of the return of the portfolio of traded assets. As we will see later, there are a number of ways to do this. The RiskMetrics™ approach assumes that the continuously compounded return (log return) of the portfolio of traded assets over the next day is normally distributed. If an asset has price $S_t$ at $t$, the log return from $t$ to T is $\ln(S_T/S_t)$. If the log of a random variable is normally distributed, the random variable follows a **lognormal distribution**. When an asset price has a log return normally distributed, the price itself has a lognormal distribution. A normally distributed random variable can take values from minus infinity to plus infinity, while a lognormal random variable can take only positive values. This makes the lognormal distribution attractive for prices of financial assets. Figure 4.3 compares the normal and lognormal distributions.

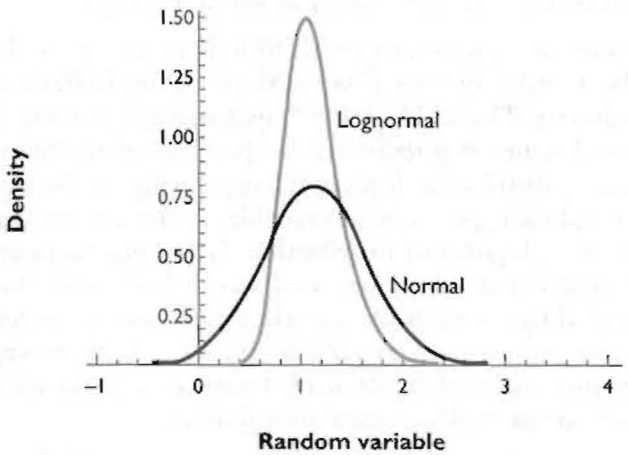
We have seen that when a portfolio has a normally distributed return the 5 percent VaR can be obtained by multiplying the forecast of the volatility of the return of the portfolio by 1.65 (when the expected return can be ignored). Consequently, to obtain an estimate of the VaR, the RiskMetrics™ approach has to come up with an estimate of the volatility of the return of the portfolio. We remember from Chapter 2 that to obtain the volatility of the return of a portfolio, we require knowledge of portfolio weights, of the return volatility of the assets that compose the portfolio, and of the return correlations among these assets. This presents three problems. First, we must have a complete inventory of the asset holdings. Second, a bank like JP Morgan would have tens of thousands of different assets in its portfolio. (As another example, the hedge fund LTCM had 60,000 different positions at the time of its collapse.) Some way to simplify the computations has to be found since otherwise millions of correlations would have to be estimated (if the bank has 100,000 assets, one would have to estimate the correlation of each asset return with the other 99,999 assets). Third, an approach to forecast volatilities and correlations has to be devised.

The inventory problem would seem to be straightforward since presumably a bank knows which assets it has at a point in time. However, a moment's reflection suggests that it is more complicated than that. JP Morgan, for example, was making markets from 20 different locations and had more than 100 trading units. All the information has to be available at one point in time so that the appropriate computations can be performed. A bank may have this information at one point in time, but perhaps not in a usable form—some of it might be in written form, some might be on one computer system, and some might be on another computer system. Also, to compute the volatility of a portfolio, portfolio weights have to be available, which requires knowledge of prices. All the prices used have to be accurate, which again may be a problem. What if an asset has not traded for the last month? A process has to be devised that makes it possible to have price estimates for all the assets included in the VaR computation.

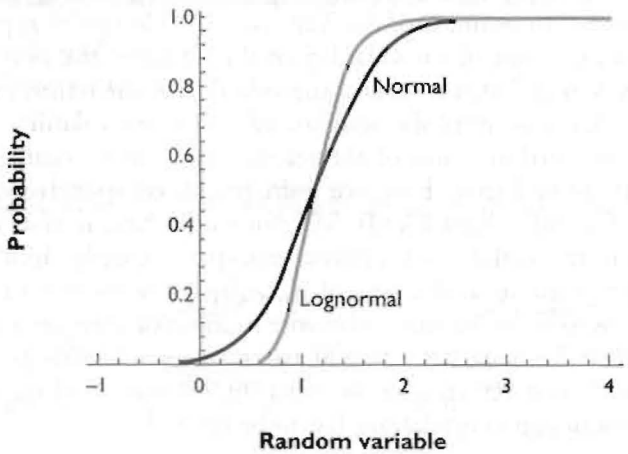
*Figure 4.3* Normal and lognormal density and cumulative distribution functions

The random variable has mean of 1.1 and volatility of 0.25. With the normal distribution, negative values are possible. The normal density function is symmetric, but the lognormal is not. The lognormal distribution has positive skewness because a lognormal variable can take large positive values, but can never take negative values.

Panel A. Density distribution functions




Panel B. Cumulative distribution functions




Since it is not practical to compute millions of correlations, RiskMetrics™ uses a mapping procedure. Rather than focusing on the volatilities and correlations of thousands of assets, RiskMetrics maps the bank's portfolio into broad asset classes, the RiskMetrics™ assets, for which it forecasts volatilities and correlations. For example, RiskMetrics™ does not use volatilities of individual stocks, but rather treats a portfolio of stocks in one country as an investment in that country's market portfolio. Similarly, it does not compute the volatility for each T-bill, T-note, and T-bond, but treats each government security as a portfolio of zero-coupon bonds and provides volatilities and correlations for a number

of different zero-coupon bonds. At the end of 2001, RiskMetrics™ provided daily volatilities and correlations for assets in 33 countries. Its daily dataset had 387 volatilities and 74,691 correlations. To obtain a VaR estimate using the RiskMetrics™ approach, we must therefore map the portfolio we have into a portfolio of RiskMetrics™ assets.

Finally, RiskMetrics™ requires the use of forecasts of volatilities and correlations. Volatilities and correlations change over time, sometimes sharply. There are periods when volatilities tend to be high because there is a great deal of uncertainty about the future. For example, stock and bond volatilities across the world were extremely high in the fall of 1998. Tremendous effort has been expanded to devise models for forecasting volatility. The main lesson from all this effort is that volatility is predictable at short horizons. If volatility was high over the last week for a financial asset, then it can be expected to be high tomorrow. However, the fact that volatility was high over the last week does not mean it will be high in six months. The persistence of volatility is short-term. Since, with daily VaR, we are attempting to estimate volatility over the next day, the persistence of volatility has to be taken into account.

The way RiskMetrics™ takes into account the fact that volatility is predictable is by giving more weight to recent observations in computing volatility forecasts. Suppose you want to estimate daily volatility for the S&P 500. You could obtain such an estimate the way you would typically estimate the volatility of a random variable: by taking the square root of the average of past squared returns. However, if you were to weight every squared return equally, you would ignore the fact that high recent volatility means that volatility tomorrow is going to be high. You can remedy this by putting more weight on recent observations. RiskMetrics™ uses declining weights in weighting past observations, so that the most recent returns affect the estimate of volatility more than returns six months ago.

With this approach, RiskMetrics™ assumes that the distribution of returns changes over time. Consequently, it cannot be that returns are drawn from a normal distribution with unchanging mean and volatility. Instead, the conditional distribution of returns is normal—meaning that conditional on the information available today, the distribution of tomorrow's return is normal, but the normal distribution from which the return is drawn for the next day will change as new information becomes available.

When JP Morgan first made RiskMetrics™ available, it made it possible for everybody to download the forecasts of the volatilities and correlations freely from the Internet. Further, it made available all the technical details of how to implement the RiskMetrics™ approach. RiskMetrics continues to make these datasets available, but now the forecasts for the next day are no longer freely available—they are free with a six-month lag.

### 4.1.3. Measuring cash flow at risk in a nonfinancial firm

Let's now consider a manufacturing firm that exports a product, Export Inc. The firm has foreign currency receivables and, consequently, has exposure to foreign exchange rate risks. Let's say it does not currently hedge, does not have derivatives or financial assets, and cannot raise outside funds. This firm views its main risk as the risk that it will have a cash flow shortfall relative to expected cash flow that

is large enough to endanger the firm's ability to remain in business and finance the investments it wants to undertake.

A bad cash flow for a week or a month is not a problem for such a firm. Cash flows are random and seasonal; some weeks or some months will have lower cash flows. Export Inc. has a problem if bad cash flows cumulate, so it is concerned about cash flows over a longer period of time, such as a year or more.

The risk that concerns the firm is the likelihood that it will have a cash shortfall over the coming fiscal year. Low cash flow by the end of that year will force it to change its plans. It has the funds available to carry on with its investment plans for this year, and it has enough reserves that it can ride out the year.

To evaluate the risk that cash flow will be low enough to create problems, Export Inc. has to forecast the distribution of its cash flow. It has two choices. If a specific cash flow level is the lowest the firm can have without incurring costs of financial distress, it can use the cumulative distribution of cash flow to determine the probability of a cash flow lower than this threshold. Alternatively, the firm can decide it will not allow the probability of serious problems to exceed some level. In this case, it evaluates the cash flow shortfall corresponding to that probability level. If the cash flow shortfall at that probability level is too great, the firm has to take actions to reduce the risk of its cash flow.

This last approach is equivalent to the VaR approach, except that it is applied to cash flow. The cash flow shortfall corresponding to the probability level chosen by the firm is thus called **cash flow at risk**, or **CaR**, at that probability level. A CaR of $100 million at the 5 percent level means that there is a probability of 5 percent that the firm's cash flow will be lower than its expected value by at least $100 million. We can therefore define cash flow at risk as follows:

### Cash flow at risk

Cash flow at risk (CaR) at $p$ percent is the cash flow shortfall (defined as expected cash flow minus realized cash flow) such that there is a probability $p$ percent that the firm will have a larger cash flow shortfall. If realized cash flow is C and expected cash flow is E(C), we have:

$$\text{Prob}[E(C) - C > \text{CaR}] = p\,\%$$

Let's look at an example of these computations. Suppose Export forecasts its cash flow for the coming year to be $80 million. The forecasted volatility is $50 million. The firm believes that the normal distribution is a good approximation of the true distribution of cash flow. It wants to make sure that there is no more than a 5 percent probability of having to cut investment and/or face financial distress. It knows it will be in this situation if its cash flow falls below $20 million. Hence, the firm wants to limit the probability that its cash flow shortfall exceeds $60 million (expected cash flow of $80 million minus cash flow of $20 million) to be at most 5 percent.

Remember that if $z$ is a random variable that follows the normal distribution, then $u = [z - E(z)]/[\text{Vol}(z)]$ follows the standard normal distribution. If $z$ is cash flow, then the absolute value of $z - E(z)$ is the shortfall of cash flow when $z$ is

lower than $E(z)$. Consequently, the cash flow shortfall at the 5 percent probability level is given by $-1.65 = -$[Cash flow shortfall]/[Volatility of cash flow], or $1.65 \times$ [Volatility of cash flow] is the cash flow shortfall or CaR at the 5 percent probability level. It follows that for our example the CaR is equal to 1.65 times volatility, or $1.65 \times \$50$ million, which corresponds to a cash flow shortfall of \$82.5 million. This means there is a 5 percent probability that the cash flow shortfall will be at least \$82.5 million or, alternatively, that cash flow will be lower than –\$2.5 million (\$80 million minus \$82.5 million). Since the CaR exceeds the firm's target, the cash flow is too risky for the firm to achieve its goal. It must therefore take actions that reduce the risk of cash flow and ensure that 95 percent of the time it will earn at least \$20 million.

How would Export estimate CaR? It would have to forecast cash flow and its distribution. To do that, it would have to figure out the risk factors that affect its cash flow and estimate their distribution. Conceptually, this would be similar to forecasting the risk factors for VaR. In practice, there are some differences. First, with CaR, we have to forecast the distribution of risk factors for one year instead of perhaps one day for VaR. Second, the impact of risk factors on cash flow is often complicated because cash flow can be a nonlinear function of a risk factor. For example, if a firm sells computers in France, the number of computers sold as well as their price in France may depend on the dollar price of the euro. We examine this issue in Chapter 8.

### 4.1.4. VaR or CaR?

Should a corporation measure and control firm value at risk, cash flow at risk, or both? A firm that depends solely on its cash flow to take advantage of its growth opportunities has to manage the risk of cash flow for the coming year. Otherwise, the firm can incur costs of financial distress and may have to cut investment if its cash flow is unexpectedly low. CaR is a measure of the risk that cash flow will fall below some critical value. It is therefore an appropriate risk measure for such a firm. A risk measure that focuses on the risk of the total market value of the firm would not be appropriate because controlling that risk measure would not enable the firm to implement its investment program: Firm value could be high even though cash flow for the year is low.

The reasoning changes if the firm has other resources to finance investment. This will be the case if the firm has assets (including financial assets) that it can sell to finance investment or it has access to capital markets to raise funds. A firm can choose to liquidate assets, especially financial assets, if its cash flow is low. It may have to reduce investment if it simultaneously has low cash flow from operations and the assets that can be liquidated to finance capital expenditures have low value. The CaR measure can be extended in a straightforward way in this case. Instead of focusing solely on cash flow from operations, the firm adds to cash flow from operations the change in the value of the assets that can be sold to finance investment. It then computes the CaR on this measure of cash available for investment.

A firm that has access to capital markets has resources to finance next year's investments in addition to this year's cash flow. If its credit is good, it will be able to raise funds at low cost. If its credit deteriorates, the firm may find it too expensive to access capital markets. To the extent that the firm's credit does not

depend only on the coming year's cash flow, it is not enough for the firm to measure the risk of this year's cash flow.

Generally, firm value is an important determinant of a firm's ability to raise funds. If the firm can freely use the capital markets to make up for cash flow shortfalls as long as its value is sufficiently high, then the relevant risk measure is firm value risk. A firm's value is the present value of its cash flows. This means that firm value risk depends on the risk of all future cash flows. The appropriate measure of firm value risk is firm VaR.

Most firms are somewhere between free access to capital markets and dependent only on the cash flow of this year to finance next year's investment. Not surprisingly, investment banks pay a lot of attention to VaR. For example, in November 2000, Goldman Sachs had a firm-wide one-day VaR for its trading instruments of $22 million. The firm-wide VaR was computed assuming normally distributed returns and a 5 percent probability level. At the same time, however, Goldman Sachs had many assets that were nontraded assets. It computed a measure similar to CaR by estimating the impact on its net revenue from changes in the fair value of its nontraded assets of a 10 percent drop in the S&P 500. It assessed the loss in net revenue to be $240 million. Many nonfinancial firms estimate a VaR for the derivative products they hold. Dell Computers computes a VaR for its foreign exchange derivative instruments and reported a one-day 5 percent VaR of $21.4 million on February 2, 2001.

In measuring cash flow at risk, nonfinancial firms have focused on measuring the risk resulting from specific market risks, such as currency risks, or from most market risks they face. For example, at the end of 2000, Ford estimated that it had a 1 percent probability of a cash flow shortfall in excess of $300 million over the next 18 months because of exchange rate fluctuations. Another firm, BHP, an Australian conglomerate, estimated its CaR taking into account all market risks to be A$1.6 billion. Cash flow is not affected by market risks only. For example, a firm's cash flow could fall dramatically because of a new competitor. However, firms have so far done little to integrate such risks in their cash flow at risk measures.

## 4.2. VaR, CaR, and firm value

Firms measure risk because risk impacts shareholder wealth. To maximize shareholder wealth, firms have to control their risk so that they have the optimal amount of risk. Therefore, if the firm cares about risk measured by VaR or CaR, it has to evaluate all its actions in light of their impact on its risk measure. If increases in a firm's risk are costly, the firm will reject some projects because of their impact on its risk, or it might choose to undertake projects because they reduce its risk—for example, it might take positions in derivatives to hedge. This means that computing the NPV of a project as a stand-alone project and taking all positive NPV projects is not the right solution for a firm that is concerned about VaR or CaR.

We consider how firms choose projects when VaR or CaR is costly, and show how they should evaluate the profitability of their activities.