CHAPTER 25

Derivatives and Hedging Risk

Executive Summary

Hardly a day seems to go by without a story in the popular press about some firm that has taken a major hit to its bottom line from its activities in the derivatives markets. Perhaps the largest losses due to derivative trading involved the U.S. firm MG Refining and Marketing (MGRM) and its German parent Metallgesellschaft (MGAG).[1] In late 1993 and early 1994, the financial press reported more than $1 billion of losses from MGRM's trading in oil futures. MGAG is one of Germany's largest industrial firms, generating more than $17 billion in sales revenue in 1993. It has been a closely held firm with 65 percent of its ownership in the hands of seven large institutional owners including the Deutsche Bank, one of the largest banks in the world.

MGRM's derivatives were a central element in its marketing strategy in which it attempted to offset customers' long-term price guarantees (up to 10 years) on gasoline, heating oil, and diesel fuel purchased from MGRM with futures trading. How did MGRM hedge its resulting exposure to spot price increases? Why did MGRM lose so much money? These are some of the questions that we will address in this chapter.

MGRM is not the only firm with reportedly large losses because of derivatives. Procter & Gamble and Gibson Greeting Cards have allegedly lost hundreds of millions of dollars in trading derivatives. The trading of derivatives by Nicholas Leeson is widely credited with having brought down the venerable international merchant bank of Barings. In addition, we have the Piper Jaffrey funds in which investors in a supposedly secure medium-term government bond fund lost 50 percent of their value, and Orange County (California), whose investments lost so much that there was concern about whether basic public services would be disrupted. Whether all of these really happened because of the use or misuse of derivatives will probably be settled years later in the courts, but in the court of public opinion, the culprit has been named—derivatives—and regulators and politicians are deciding on the sentence.

In this chapter we take a close look at derivatives—what they are, how they work, and the uses to which they can be put. When we are done, you will understand how financial derivatives are designed, and you will be able to decide for yourself in an informed fashion what is happening when the next derivatives scandal erupts.

Derivatives, Hedging, and Risk

The name *derivatives* is self-explanatory. A derivative is a financial instrument whose payoffs and values are derived from, or depend on, something else. Often we speak of the thing that the derivative depends on as the *primitive* or the *underlying.* For example, in Chapter 22 we studied how options work. An option is a derivative. The value of a call option depends on the value of the underlying stock on which it is written. Actually, call options are

[1] C. Culp and M. Miller, "Metallgesellschaft and the Economics of Synthetic Storage," *Journal of Applied Corporate Finance* (Winter 1995), discuss the MGRM derivative losses.

quite complicated examples of derivatives. The vast majority of derivatives are simpler than call options. Most derivatives are forward or futures agreements or what are called swaps, and we will study each of these in some detail.

Why do firms use derivatives? The answer is that derivatives are tools for changing the firm's risk exposure. Someone once said that derivatives are to finance what scalpels are to surgery. By using derivatives, the firm can cut away unwanted portions of risk exposure and even transform the exposures into quite different forms. A central point in finance is that risk is undesirable. In our chapters on risk and return, we pointed out that individuals would choose risky securities only if the expected return compensated for the risk. Similarly, a firm will accept a project with high risk only if the return on the project compensates for this risk. Not surprisingly, then, firms are usually looking for ways to reduce their risk. When the firm reduces its risk exposure with the use of derivatives, it is said to be **hedging.** Hedging offsets the firm's risk, such as the risk in a project, by one or more transactions in the financial markets.

Derivatives can also be used to merely change or even increase the firm's risk exposure. When this occurs, the firm is **speculating** on the movement of some economic variables—those that underlie the derivative. For example, if a derivative is purchased that will rise in value if interest rates rise, and if the firm has no offsetting exposure to interest rate changes, then the firm is speculating that interest rates will rise and give it a profit on its derivatives position. Using derivatives to translate an opinion about whether interest rates or some other economic variable will rise or fall is the opposite of hedging—it is risk enhancing. Speculating on your views on the economy and using derivatives to profit if that view turns out to be correct is not necessarily wrong, but the speculator should always remember that sharp tools cut deep, and if the opinions on which the derivatives position is based turn out to be incorrect, then the consequences can prove costly. Efficient market theory teaches how difficult it is to predict what markets will do. Most of the sad experiences with derivatives have occurred not from their use as instruments for hedging and offsetting risk, but, rather, from speculation.

25.1 Forward Contracts

We can begin our discussion of hedging by considering forward contracts. One frequently hears the one-liner about the gentleman who was shocked to find he had been speaking prose all his life. Forward contracts are a lot like that; you have probably been dealing in them your whole life without knowing it. Suppose you walk into a bookstore on, say, February 1 to buy the best-seller *Eating Habits of the Rich and Famous.* The cashier tells you that the book is currently sold out, but he takes your phone number, saying that he will reorder it for you. He says the book will cost $10.00. If you agree on February 1 to pick up and pay $10.00 for the book when called, you and the cashier have engaged in a **forward contract.** That is, you have agreed both to pay for the book and to pick it up when the bookstore notifies you. Since you are agreeing to buy the book at a later date, you are *buying* a forward contract on February 1. In commodity parlance, you will be **taking delivery** when you pick up the book. The book is called the **deliverable instrument.**

The cashier, acting on behalf of the bookstore, is selling a forward contract. (Alternatively, we say that he is writing a forward contract.) The bookstore has agreed to turn the book over to you at the predetermined price of $10.00 as soon as the book arrives. The act of turning the book over to you is called **making delivery.** Table 25.1 illustrates the book purchase. Note that the agreement takes place on February 1. The price is set and the

TABLE 25.1 Illustration of Book Purchase as a Forward Contract

February 1	Date When Book Arrives
Buyer	
Buyer agrees to:	Buyer:
1. Pay the purchase price of $10.00.	1. Pays purchase price of $10.00.
2. Receive book when book arrives.	2. Receives book.
Seller	
Seller agrees to:	Seller:
1. Give up book when book arrives.	1. Gives up book.
2. Accept payment of $10.00 when book arrives.	2. Accepts payment of $10.00.

Note that cash does not change hands on February 1. Cash changes hands when the book arrives.

conditions for sale are set at that time. In this case, the sale will occur when the book arrives. In other cases, an exact date of sale would be given. However, *no* cash changes hands on February 1; cash changes hands only when the book arrives.

Though forward contracts may have seemed exotic to you before you began this chapter, you can see that they are quite commonplace. Dealings in your personal life probably have involved forward contracts. Similarly, forward contracts occur all the time in business. Every time a firm orders an item that cannot be delivered immediately, a forward contract takes place. Sometimes, particularly when the order is small, an oral agreement will suffice. Other times, particularly when the order is larger, a written agreement is necessary.

Note that a forward contract is not an option. Both the buyer and the seller are obligated to perform under the terms of the contract. Conversely, the buyer of an option *chooses* whether or not to exercise the option.

A forward contract should be contrasted with a **cash transaction,** that is, a transaction where exchange is immediate. Had the book been on the bookstore's shelf, your purchase of it would constitute a cash transaction.

CONCEPT QUESTIONS ?

- What is a forward contract?
- Give examples of forward contracts in your life.

25.2 FUTURES CONTRACTS

A variant of the forward contract takes place on financial exchanges. Contracts on exchanges are usually called **futures contracts.** For example, consider Table 25.2, which provides data on trading in wheat for Thursday, September 15, 20X1. Let us focus on the September futures contract, which is illustrated in the first row of the table. The first trade of the day in the contract was for $4.11 per bushel. The price reached a high of $4.16 ¼ during the day and reached a low of $4.07. The last trade was also at $4.07. In other words, the contract *closed* or *settled* at $4.07. The price dropped 6¼ cents per bushel during the day, indicating that the price closed the previous day at $4.13¼ ($4.07 + $0.0625). The contract had been trading for slightly less than a year. During that time, the price reached a high of $4.21 per bushel and a low of $2.72 per bushel. The open interest indicates the number of *contracts outstanding.* The number of contracts outstanding at the close of September 15 was 423.

■ TABLE 25.2 **Data on Wheat Futures Contracts, Thursday, September 15, 20X1**

						Lifetime		
	Open	High	Low	Settle	Change	High	Low	Open Interest
Sept	411	416¼	407	407	−6¼	421	272	423
Oct	427	432¼	422	423¼	−5½	432¼	289	47,454
Mar X2	430½	436	426½	427	−4¼	436	323	42,823
May	409	443½	404	405	−5½	420	330	3,422
July	375	376½	369	370¾	−6¾	395	327	4,805

Though we are discussing a futures contract, let us work with a forward contract first. Suppose you wrote a *forward* contract for September wheat at $4.07. From our discussion on forward contracts, this would mean that you would agree to turn over an agreed-upon number of wheat bushels for $4.07 per bushel on some specified date in the remainder of the month of September.

A futures contract differs somewhat from a forward contract. First, the seller can choose to deliver the wheat on any day during the delivery month, that is, the month of September. This gives the seller leeway that he would not have with a forward contract. When the seller decides to deliver, he notifies the exchange clearinghouse that he wants to do so. The clearinghouse then notifies an individual who bought a September wheat contract that she must stand ready to accept delivery within the next few days. Though each exchange selects the buyer in a different way, the buyer is generally chosen in a random fashion. Because there are so many buyers at any one time, the buyer selected by the clearinghouse to take delivery almost certainly did not originally buy the contract from the seller now making delivery.

Second, futures contracts are traded on an exchange whereas forward contracts are generally traded off an exchange. Because of this, there is generally a liquid market in futures contracts. A buyer can net out her futures position with a sale. A seller can net out his futures position with a purchase. This procedure is analogous to the *netting-out* process in the options markets. However, the buyer of an options contract can also walk away from the contract by not exercising it. If a buyer of a futures contract does not subsequently sell her contract, she must take delivery.

Third, and most important, the prices of futures contracts are **marked to the market** on a daily basis. That is, suppose that the price falls to $4.05 on Friday's close. Because all buyers lost two cents per bushel on that day, they each must turn over the two cents per bushel to their brokers within 24 hours, who subsequently remit the proceeds to the clearinghouse. Because all sellers gained two cents per bushel on that day, they each receive two cents per bushel from their brokers. Their brokers are subsequently compensated by the clearinghouse. Because there is a buyer for every seller, the clearinghouse must break even every day.

Now suppose that the price rises to $4.12 on the close of the following Monday. Each buyer receives seven cents ($4.12 − $4.05) per bushel and each seller must pay seven cents per bushel. Finally, suppose that, on Monday, a seller notifies his broker of his intention to deliver.[2] The delivery price will be $4.12, which is Monday's close.

There are clearly many cash flows in futures contracts. However, after all the dust settles, the *net price* to the buyer must be the price at which she bought originally. That is, an individual buying at Thursday's closing price of $4.07 and being called to take delivery on Monday

[2]He will deliver on Wednesday, two days later.

ILLUSTRATION OF EXAMPLE INVOLVING MARKING TO MARKET IN FUTURES CONTRACTS

Both buyer and seller originally transact at Thursday's closing price. Delivery takes place at Monday's closing price.*

	Thursday, September 19	Friday, September 20	Monday, September 23	Delivery (notification given by seller on Monday)
Closing price:	$4.07	$4.05	$4.12	
BUYER	Buyer purchases futures contract at closing price of $4.07/bushel.	Buyer must pay two cents/ bushel to clearinghouse within one business day.	Buyer receives seven cents/ bushel from clearinghouse within one business day.	Buyer pays $4.12 per bushel and receives grain within one business day.

Buyer's net payment of −$4.07 (−$0.02 + $0.07 − $4.12) is the same as if buyer purchased a forward contract for $4.07/bushel.

SELLER	Seller sells futures contract at closing price of $4.07/bushel.	Seller receives two cents/ bushel from clearinghouse within one business day.	Seller pays seven cents/ bushel to clearinghouse within one business day.	Seller receives $4.12 per bushel and delivers grain within one business day.

Seller's net receipts of $4.07 ($0.02 − $0.07 + $4.12) are the same as if seller sold a forward contract for $4.07/bushel.

*For simplicity, we assume that buyer and seller both (1) initially transact at the same time and (2) meet in delivery process. This is actually very unlikely to occur in the real world because the clearinghouse assigns the buyer to take delivery in a random manner.

pays two cents per bushel on Friday, receives seven cents per bushel on Monday, and takes delivery at $4.12. Her net outflow per bushel is −$4.07 (−$0.02 + $0.07 − $4.12), which is the price at which she contracted on Thursday. (Our analysis ignores the time value of money.) Conversely, an individual selling at Thursday's closing price of $4.07 and notifying his broker concerning delivery the following Monday receives two cents per bushel on Friday, pays seven cents per bushel on Monday and makes delivery at $4.12. His net inflow per bushel is $4.07 ($0.02 − $0.07 + $4.12), which is the price at which he contracted on Thursday.

These details are presented in the adjacent box. For simplicity, we assumed that the buyer and seller who initially transact on Thursday's close meet in the delivery process.[3] The point in the example is that the buyer's net payment of $4.07 per bushel is the same as if she purchased a forward contract for $4.07. Similarly, the seller's net receipt of $4.07 per bushel is the same as if he sold a forward contract for $4.07 per bushel. The only difference

[3]As pointed out earlier, this is actually very unlikely to occur in the real world.

is the timing of the cash flows. The buyer of a forward contract knows that he will make a single payment of \$4.07 on the expiration date. He will not need to worry about any other cash flows in the interim. Conversely, though the cash flows to the buyer of a futures contract will net to exactly \$4.07 as well, the pattern of cash flows is not known ahead of time.

The mark-to-the-market provision on futures contracts has two related effects. The first concerns differences in net present value. For example, a large price drop immediately following purchase means an immediate outpayment for the buyer of a futures contract. Though the net outflow of \$4.07 is still the same as under a forward contract, the present value of the cash outflows is greater to the buyer of a futures contract. Of course, the present value of the cash outflows is less to the buyer of a futures contract if a price rise followed purchase.[4] Though this effect could be substantial in certain theoretical circumstances, it appears to be of quite limited importance in the real world.[5]

Second, the firm must have extra liquidity to handle a sudden outflow prior to expiration. This added risk may make the futures contract less attractive.

Students frequently ask, "Why in the world would managers of the commodity exchanges ruin perfectly good contracts with these bizarre mark-to-the-market provisions?" Actually, the reason is a very good one. Consider the forward contract of Table 25.1 concerning the bookstore. Suppose that the public quickly loses interest in *Eating Habits of the Rich and Famous.* By the time the bookstore calls the buyer, other stores may have dropped the price of the book to \$6.00. Because the forward contract was for \$10.00, the buyer has an incentive not to take delivery on the forward contract. Conversely, should the book become a hot item selling at \$15.00, the bookstore may simply not call the buyer.

As indicated, forward contracts have a very big flaw. Whichever way the price of the deliverable instrument moves, one party has an incentive to default. There are many cases where defaults have occurred in the real world. One famous case concerned Coca-Cola. When the company began in the early 20th century, Coca-Cola made an agreement to supply its bottlers and distributors with cola syrup at a constant price *forever.* Of course, subsequent inflation would have caused Coca-Cola to lose large sums of money had they honored the contract. After much legal effort, Coke and its bottlers put an *inflation-escalator clause* in the contract. Another famous case concerned Westinghouse. It seems the firm had promised to deliver uranium to certain utilities at a fixed price. The price of uranium skyrocketed in the 1970s, making Westinghouse lose money on every shipment. Westinghouse defaulted on its agreement. The utilities took Westinghouse to court but did not recover amounts anything near what Westinghouse owed them.

The mark-to-the-market provisions minimize the chance of default on a futures contract. If the price rises, the seller has an incentive to default on a forward contract. However, after paying the clearinghouse, the seller of a futures contract has little reason to default. If the price falls, the same argument can be made for the buyer. Because changes in the value of the underlying asset are recognized daily, there is no accumulation of loss, and the incentive to default is reduced.

Because of this default issue, forward contracts generally involve individuals and institutions who know and can trust each other. But as W. C. Fields said, "Trust everybody, but cut the cards." Lawyers earn a handsome living writing supposedly air-tight forward contracts, even among friends. The genius of the mark-to-the-market system is that is can prevent default where it is most likely to occur—among investors who do not

[4]The direction is reversed for the seller of a futures contract. However, the general point that the net present value of cash flows may differ between forward and futures contracts holds for sellers as well.

[5]See John C. Cox, John E. Ingersoll, and Steven A. Ross. "The Relationship between Forward and Future Prices," *Journal of Financial Economics* (1981).

know each other. Textbooks on futures contracts from one or two decades ago usually include a statement such as "No major default has ever occurred on the commodity exchanges." No textbook published after the Hunt Brothers defaulted on silver contracts in the 1970s can make that claim. Nevertheless, the extremely low default rate in futures contracts is truly awe-inspiring.

Futures contracts are traded in three areas: agricultural commodities, metals and petroleum, and financial assets. The extensive array of futures contracts is listed in Table 25.3.

CONCEPT QUESTIONS ?

- What is a futures contract?
- How is a futures contract related to a forward contract?
- Why do exchanges require futures contracts to be marked to the market?

TABLE 25.3 Futures Contracts Listed in *The Wall Street Journal*

Contract	Contract Size	Exchange
Agricultural (grain and oilseeds)		
Corn	5,000 bushels	Chicago Board of Trade (CBT)
Oats	5,000 bushels	CBT
Soybeans	5,000 bushels	CBT
Soybean meal	400 tons	CBT
Soybean oil	60,000 lbs.	CBT
Wheat	5,000 bushels	CBT
Wheat	5,000 bushels	Kansas City (KC)
Wheat	5,000 bushels	Minneapolis
Barley	20 metric tons	Winnipeg (WPG)
Flaxseed	20 metric tons	WPG
Rapeseed	20 metric tons	WPG
Wheat	20 metric tons	WPG
Rye	20 metric tons	WPG
Agricultural (livestock and meat)		
Cattle (feeder)	44,000 lbs.	Chicago Mercantile Exchange (CME)
Cattle (live)	40,000 lbs.	CME
Hogs	30,000 lbs.	CME
Pork bellies	40,000 lbs.	CME
Agricultural (food, fiber, and wood)		
Cocoa	10 metric tons	Coffee, Sugar and Cocoa Exchange (CSCE)
Coffee	37,500 lbs.	CSCE
Cotton	50,000 lbs.	New York Cotton Exchange (CTN)
Orange juice	15,000 lbs.	CTN
Sugar (world)	112,000 lbs.	CSCE
Sugar (domestic)	142,000 lbs.	CSCE
Lumber	150,000 board feet	CME

TABLE 25.3 (*concluded*)

Contract	Contract Size	Exchange
Metals and petroleum		
Copper (standard)	25,000 lbs.	Commodity Exchange in New York (CMX)
Gold	100 troy oz.	CMX
Platinum	50 troy oz.	New York Mercantile (NYM)
Palladium	100 troy oz.	NYM
Silver	5,000 troy oz.	CMX
Silver	1,000 troy oz.	CBT
Crude oil (light sweet)	1,000 barrels	NYM
Heating oil no. 2	42,000 gallons	NYM
Gas oil	100 metric tons	International Petroleum Exchange of London (IPEL)
Gasoline unleaded	42,000 gallons	NYM
Financial		
British pound	62,500 pounds	International Monetary Market in Chicago (IMM)
Australian dollar	100,000 dollars	IMM
Canadian dollar	100,000 dollars	IMM
Japanese yen	12.5 million yen	IMM
Swiss franc	125,000 francs	IMM
German mark	125,000 marks	IMM
Eurodollar	$1 million	London International Financial Futures Exchange (LIFFE)
Financial		
Sterling	500,000 pounds	LIFFE
Treasury bonds	$1 million	LIFFE
Long gilt	250,000 pounds	LIFFE
Eurodollar	$1 million	IMM
U.S. Dollar Index	500 times Index	Financial Instrument Exchange in New York (FINEX)
CRB Index	500 times Index	New York Futures Exchange (NYFE)
Treasury bonds	$100,000	CBT
Treasury notes	$100,000	CBT
5-year Treasury notes	$100,000	CBT
5-year Treasury notes	$100,000	FINEX
Treasury bonds	$50,000	MCE
Treasury bonds	$1 million	IMM
Financial indexes		
Municipal bonds	1,000 times Bond Buyer Index	CBT
S&P 500 Index	500 times Index	CME
NYSE Composite	500 times Index	NYFE
Kansas City Value Line Index	500 times Index	KC
Major Market Index	250 times Index	CBT

25.3 HEDGING

Now that we have determined how futures contracts work, let us talk about hedging. There are two types of hedges, long and short. We discuss the short hedge first.

EXAMPLE

In June, Bernard Abelman, a Midwestern farmer, anticipates a harvest of 50,000 bushels of wheat at the end of September. He has two alternatives.

1. *Write Futures Contracts against His Anticipated Harvest.* The September wheat contract on the Chicago Board of Trade is trading at $3.75 a bushel on June 1. He executes the following transaction:

Date of Transaction	Transaction	Price per Bushel
June 1	Write 10 September futures contracts	$3.75

He notes that transportation costs to the designated delivery point in Chicago are 30 cents/bushel. Thus, his net price per bushel is $3.45 = $3.75 − $0.30.

2. *Harvest the Wheat without Writing a Futures Contract.* Alternatively, Mr. Abelman could have harvested the wheat without benefit of a futures contract. The risk would be quite great here since no one knows what the cash price in September will be. If prices rise, he will profit. Conversely, he will lose if prices fall.

We say that strategy 2 is an unhedged position because there is no attempt to use the futures markets to reduce risk. Conversely, strategy 1 involves a hedge. That is, a position in the futures market offsets the risk of a position in the physical, that is, in the actual, commodity.

Though hedging may seem quite sensible to you, it should be mentioned that not everyone hedges. Mr. Abelman might reject hedging for at least two reasons.

First, he may simply be uninformed about hedging. We have found that not everyone in business understands the hedging concept. Many executives have told us that they do not want to use futures markets for hedging their inventories because the risks are too great. However, we disagree. While there are large price fluctuations in these markets, hedging actually reduces the risk that an individual holding inventories bears.

Second, Mr. Abelman may have a special insight or some special information that commodity prices will rise. He would not be wise to lock in a price of $3.75 if he expects the cash price in September to be well above this price.

The hedge of strategy 1 is called a **short hedge,** because Mr. Abelman reduces his risk by *selling* a futures contract. The short hedge is very common in business. It occurs whenever someone either anticipates receiving inventory or is holding inventory. Mr. Abelman was anticipating the harvest of grain. A manufacturer of soybean meal and oil may hold large quantities of raw soybeans, which are already paid for. However, the price to be received for meal and oil are not known because no one knows what the market price will be when the meal and oil are produced. The manufacturer may write futures contracts in meal and oil to lock in a sales price. An oil company may hold large inventories of petroleum to be processed into heating oil. The firm could sell futures contracts in heating oil in order to lock in the sales price. A mortgage banker may assemble mortgages slowly before selling them in bulk to a financial institution. Movements of interest rates affect the value of the mortgages during the time they are in inventory. The mortgage banker could sell Treasury-bond futures contracts in order to offset this interest-rate risk. (This last example is treated later in this chapter.)

EXAMPLE

On April 1, Moon Chemical agreed to sell petrochemicals to the U.S. government in the future. The delivery dates and prices have been determined. Because oil is a basic ingredient of the production process, Moon Chemical will need to have large quantities of oil on hand. The firm can get the oil in one of two ways:

1. *Buy the Oil As the Firm Needs It.* This in an unhedged position because, as of April 1, the firm does not know the prices it will later have to pay for the oil. Oil is quite a volatile commodity, so Moon Chemical is bearing a good bit of risk. The key to this risk-bearing is that the sales price to the U.S. government has already been fixed. Thus, Moon Chemical cannot pass on increased costs to the consumer.
2. *Buy Futures Contracts.*[6] The firm can buy futures contracts with expiration months corresponding to the dates the firm needs inventory. The futures contract locks in the purchase price to Moon Chemical. Because there is a crude-oil futures contract for every month, selecting the correct futures contract is not difficult. Many other commodities have only five contracts per year, frequently necessitating buying contracts one month away from the month of production.

As mentioned earlier, Moon Chemical is interested in hedging the risk of fluctuating oil prices because it cannot pass any cost increases on to the consumer. Suppose, alternatively, that Moon Chemical was not selling petrochemicals on fixed contract to the U.S. government. Instead, imagine that the petrochemicals were to be sold to private industry at currently prevailing prices. The price of petrochemicals should move directly with oil prices, because oil is a major component of petrochemicals. Because cost increases are likely to be passed on to the consumer, Moon Chemical would probably not want to hedge in this case. Instead, the firm is likely to choose strategy 1, buying the oil as it is needed. If oil prices increase between April 1 and September 1, Moon Chemical will, of course, find that its inputs have become quite costly. However, in a competitive market, its revenues are likely to rise as well.

Strategy 2 is called a **long hedge** because one *purchases* a futures contract to reduce risk. In other words, one takes a long position in the futures market. In general, a firm institutes a long hedge when it is committed to a fixed sales price. One class of situations involves actual written contracts with customers, such as Moon Chemical had with the U.S. government. Alternatively, a firm may find that it cannot easily pass on costs to consumers or does not want to pass on these costs. For

[6]Alternatively, the firm could buy the oil on April 1 and store it. This would eliminate the risk of price movement, because the firm's oil costs would be fixed upon the immediate purchase. However, this strategy would be inferior to strategy 2 in the common case where the difference between the futures contract quoted on April 1 and the April 1 cash price is less than storage costs.

example, a group of students opened a small meat market called *What's Your Beef* near the University of Pennsylvania in the late 1970s.[7] You may recall that this was a time of volatile consumer prices, especially food prices. Knowing that their fellow students were particularly budget-conscious, the owners vowed to keep food prices constant, regardless of price movements in either direction. They accomplished this by purchasing futures contracts in various agricultural commodities.

CASE STUDY — *Making the Decision to Use Derivatives: The Case of Metallgesellschaft*

Earlier in the chapter we introduced MG Refining and Marketing (MGRM), a U.S. subsidiary of Metallgesellschaft AG (MGAG).[8] MGRM reportedly lost more than $1 billion from trading derivatives. Essentially, MGRM sold gasoline, heating oil, and diesel fuel at fixed prices for up to 10 years in the future. This is called "selling forward." In 1993 MGRM had sold forward more than 150 million barrels of petroleum products. As in any "selling forward program," MGRM would lose if the prices of petroleum products rose over time. For example, suppose MGRM had agreed to sell 150 million barrels of heating oil 10 years from now at $25 per barrel. In 10 years, if the actual price of heating oil turned out to be $35 per barrel, MGRM would stand to lose $10 for every barrel it must sell.

There are several things that MGRM could do to hedge this exposure.

1. MGRM could have attempted to acquire 150 million barrels of oil for forward delivery 10 years from now. If the 10-year forward price had been $25 per barrel, MGRM would have broken even. In theory, this would have been a perfect hedge. Unfortunately, it is almost impossible to find firms who will commit to buying or selling 150 million barrels of oil 10 years in the future. There is no organized 10-year forward market in petroleum products.
2. MGRM could have tried to buy a futures contract that would guarantee delivery of 150 million barrels of oil 10 years from now at $25 per barrel. But, as with forward trading, there is no 10-year futures market for petroleum products.
3. Because no 10-year futures contract existed, MGRM employed a "rolling stack" strategy. That is, they first bought a short-term, say, a one-year, futures contract instead of the 10-year contract. At the end of one year, when the futures contract matured, MGRM wrote another one-year futures contract. The strategy called for a series of 10 one-year futures contracts over the 10 years.

The strategy can be best understood in a two-year example. At date 0, MGRM would sell oil forward 10 years, at, say, $25 a barrel, to its customers. Simultaneously, MGRM would buy a one-year futures contract, also at $25 a barrel.[9] Now assume that the spot price of oil, i.e., the price for immediate delivery, rises to $30 a barrel at date 1. Also, at date 2, the price of the one-year futures contract sells at $30 a barrel. Here, MGRM would break even and at date 1, would gain $5 on its first one-year futures contract. That is, its futures contract issued at date 0 requires it to pay $25 for a barrel of oil

[7]Ordinarily, an unusual firm name in this textbook is a tip-off that it is fictional. This, however, is a true story.

[8]For a spirited debate on what caused the MGRM derivative trading losses, please read: F. R. Edwards and M. S. Canter, "The Collapse of Metallgesellschaft: Unhedgeable Risks, Poor Hedging Strategy or Just Bad Luck," *Journal of Applied Corporate Finance* (Spring 1995); A. S. Mello and J. E. Parsons, "Maturity Structure of a Hedge Matters: Lessons from the Metallgesellschaft Debacle," *Journal of Applied Corporate Finance* (Spring 1995); C. Culp and M. Miller, "Hedging in the Theory of Corporate Finance: A Reply to Our Critics," *Journal of Applied Corporate Finance* (Spring 1995).

[9]For simplicity, we assume a level "term structure" of oil prices. A case of nonlevel prices, while more complex, would lead to the same conclusion. We also use the term of one year when rolling stacks are usually in terms of months.

at date 1. It could immediately sell this oil in the spot market at $30 a barrel. However, at date 2, it would lose $5. That is, its futures contract issued at date 1 requires it to buy oil at $30 a barrel at date 2. This oil must be sold to its customers for only $25 at date 2.

Unfortunately, there are two potential problems with this hedge. First, the entire term structure of oil prices need not move together. For example, if the spot price of oil was only $29 at date 1 while the one-year futures contract was quoted at $30 on that date, the firm would lose $1. That is, the gain on the first contract of $4 ($29 − $25) would be less than the loss of $5 ($30 − $25) on the second contract.

Second, the first contract must be settled before the second contract, necessitating liquidity problems. For example, if oil prices fell at date 1, the loss on the first contract would be settled to that date. The gain on the second contract would occur at date 2.[10] In fact, oil prices did fall over much of the 10-year life of MGRM's hedge, causing large liquidity problems.

The above shows that risks arise even when a position is hedged. However, MGRM created a third risk (and perhaps greater risk) by eliminating their hedge in the middle. Suppose, in our example, that MGRM bought the first futures contract at date 0 but did not buy the second futures contract at date 1. That is, they did not "roll over" their hedge. Since the firm had previously sold oil forward for two years, they would be unhedged over the second year. A rise in oil prices over the second year to pay $35 would mean that MGRM would have to buy oil in the spot market at $35 on date 2 in order to simultaneously sell oil to its customers at $25. While MGRM in the real world had a 10-year contract, the effect was similar. After MGRM failed to roll over its stacked hedge, i.e., failed to buy futures contracts in later years, oil prices rose. MGRM suffered great losses because of this.

Was the decision to terminate the right one? No one can really know the answer to this important question. It may be that the funding requirements from margin calls forced MGRM into liquidating the futures leg of the hedge, precipitating the collapse. It is possible that the rolling stack hedge was not well designed and had more risks than was initially perceived. It is also possible that the program was terminated prematurely and, had MGRM hung on, the hedge would have been operative. Nevertheless, it must be pointed out that MGRM incurred quite a bit of bad luck. Oil prices fell when MGRM was hedged, leading to liquidity problems. Oil prices rose after the hedge was lifted, leading to losses. ■■■■■

Concept Questions ?

- Define short and long hedges.
- Under what circumstances is each of the two hedges used?
- What is a rolling stack strategy?

25.4 Interest-Rate Futures Contracts

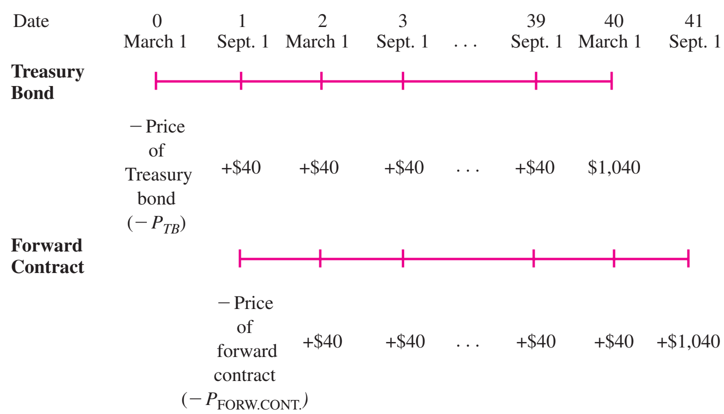
In this section we consider interest-rate futures contracts. Our examples deal with futures contracts on Treasury bonds because of their high popularity. We first price Treasury bonds and Treasury-bond forward contracts. Differences between futures and forward contracts are explored. Hedging examples are provided next.

Pricing of Treasury Bonds

As mentioned earlier in the text, a Treasury bond pays semiannual interest over its life. In addition, the face value of the bond is paid at maturity. Consider a 20-year, 8-percent coupon bond that was issued on March 1. The first payment is to occur in six months, that is, on September 1. The value of the bond can be determined as

[10]In addition, since futures contracts are marked-to-the-market daily, gains and losses on the first contract must be settled each day over the first year. If oil prices fell, margin calls would have occurred over the first year.

FIGURE 25.1 Cash Flows for Both a Treasury Bond and a Forward Contract on a Treasury Bond



Pricing of a Treasury Bond:

$$P_{TB} = \frac{\$40}{1 + r_1} + \frac{\$40}{(1 + r_2)^2} + \frac{\$40}{(1 + r_3)^3} + \ldots + \frac{\$40}{(1 + r_{39})^{39}} + \frac{\$1{,}040}{(1 + r_{40})^{40}} \quad (25.1)$$

Because an 8-percent coupon bond pays interest of $80 a year, the semiannual coupon is $40. Principal and the semiannual coupons are both paid at maturity. As we mentioned in a previous chapter, the price of the Treasury bond, P_{TB}, is determined by discounting each payment on a bond at the appropriate spot rate. Because the payments are semiannual, each spot rate is expressed in semiannual terms. That is, imagine a horizontal term structure where the effective annual yield is 12 percent for all maturities. Because each spot rate, r, is expressed in semiannual terms, each spot rate is $\sqrt{1.12} - 1 = 5.83\%$. Because coupon payments occur every six months, there are 40 spot rates over the 20-year period.

Pricing of Forward Contracts

Now, imagine a *forward* contract where, on March 1, you agree to buy a new 20-year, 8-percent coupon Treasury bond in six months, that is, on September 1. As with typical forward contracts, you will pay for the bond on September 1, not March 1. The cash flows from both the Treasury bond issued on March 1 and the forward contract that you purchase on March 1 are presented in Figure 25.1. The cash flows on the Treasury bond begin exactly six months earlier than do the cash flows on the forward contract. The Treasury bond is purchased with cash on March 1 (date 0). The first coupon payment occurs on September 1 (date 1). The last coupon payment occurs at date 40, along with the face value of $1,000. The forward contract compels you to pay $P_{FORW.CONT.}$, the price of the forward contract, on September 1 (date 1). You receive a new Treasury bond at that time. The first coupon payment from the bond you receive occurs on March 1 of the following year (date 2). The last coupon payment occurs at date 41, along with the face value of $1,000.

Given the 40 spot rates, equation (25.1) showed how to price a Treasury bond. How does one price the forward contract on a Treasury bond? Just as we saw earlier in the text that net-present-value analysis can be used to price bonds, we will now show that net-present-value analysis can be used to price forward contracts. Given the cash flows for the forward contract in Figure 25.1, the price of the forward contract must satisfy the following equation:

$$\frac{P_{\text{FORW.CONT.}}}{1 + r_1} = \frac{\$40}{(1 + r_2)^2} + \frac{\$40}{(1 + r_3)^3} + \frac{\$40}{(1 + r_4)^4} + \ldots + \frac{\$40}{(1 + r_{40})^{40}} + \frac{\$1{,}040}{(1 + r_{41})^{41}} \quad (25.2)$$

The right-hand side of equation (25.2) discounts all the cash flows from the delivery instrument (the Treasury bond issued on September 1) back to date 0 (March 1). Because the first cash flow occurs at date 2 (March 1 of the subsequent year), it is discounted by $1/(1 + r_2)^2$. The last cash flow of $1,040 occurs at date 41, so it is discounted by $1/(1 + r_{41})^{41}$. The left-hand side represents the cost of the forward contract as of date 0. Because the actual outpayment occurs at date 1, it is discounted by $1/(1 + r_1)$.

Students often ask, "Why are we discounting everything back to date 0, when we are actually paying for the forward contract on September 1?" The answer is simply that we apply the same techniques to equation (25.2) that we apply to all capital-budgeting problems; we want to put everything in today's (date 0's) dollars. Given that the spot rates are known in the marketplace, traders should have no more trouble pricing a forward contract by equation (25.2) than they would have pricing a Treasury bond by (25.1).

Forward contracts are similar to the underlying bonds themselves. If the entire term structure of interest rates unexpectedly shifts upward on March 2, the Treasury bond issued the previous day should fall in value. This can be seen from equation (25.1). A rise in each of the spot rates lowers the present value of each of the coupon payments. Hence, the value of the bond must fall. Conversely, a fall in the term structure of interest rates increases the value of the bond.

The same relationship holds with forward contracts, as can be seen from rewriting (25.2) as

$$P_{\text{FORW.CONT.}} = \frac{\$40 \times (1 + r_1)}{(1 + r_2)^2} + \frac{\$40 \times (1 + r_1)}{(1 + r_3)^3} + \frac{\$40 \times (1 + r_1)}{(1 + r_4)^4} + \ldots + \frac{\$40 \times (1 + r_1)}{(1 + r_{40})^{40}} + \frac{\$1{,}040 \times (1 + r_1)}{(1 + r_{41})^{41}} \quad (25.3)$$

We went from (25.2) to (25.3) by multiplying both the left- and the right-hand sides by $(1 + r_1)$. If the entire term structure of interest rates unexpectedly shifts upward on March 2, the *first* term on the right-hand side of equation (25.3) should fall in value.[11] That is, both r_1 and r_2 will rise an equal amount. However, r_2 enters as a *squared* term, $1/(1 + r_2)^2$, so an increase in r_2 more than offsets the increase in r_1. As we move further to the right, an increase in any spot rate, r_i, more than offsets an increase in r_1. Here r_i enters as the *i*th power, $1/(1 + r_i)^i$. Thus, as long as the entire term structure shifts upward an equal amount on March 2, the value of a forward contract must fall on that date. Conversely, as long as the entire term structure shifts downward an equal amount on March 2, the value of a forward contract must rise.

[11]We are assuming that each spot rate shifts the same amount. For example, suppose that, on March 1, $r_1 = 5\%$, $r_2 = 5.4\%$, and $r_3 = 5.8\%$. Assuming that all rates increase by 1/2 percent on March 2, r_1 becomes 5.5 percent (5% + 1/2%), r_2 becomes 5.9 percent, and r_3 becomes 6.3 percent.

Futures Contracts

The above discussion concerned a forward contract in U.S. Treasury bonds, that is, a forward contract where the deliverable instrument is a U.S. Treasury bond. What about a futures contract on a Treasury bond?[12] We mentioned earlier that futures contracts and forward contracts are quite similar, though there are a few differences between the two. First, futures contracts are generally traded on exchanges, whereas forward contracts are not traded on an exchange. In this case, the Treasury-bond futures contract is traded on the Chicago Board of Trade. Second, futures contracts generally allow the seller a period of time in which to deliver, whereas forward contracts generally call for delivery on a particular day. The seller of a Treasury-bond futures contract can choose to deliver on any business day during the delivery month.[13] Third, futures contracts are subject to the mark-to-the-market convention, whereas forward contracts are not. Traders in Treasury-bill futures contracts must adhere to this convention. Fourth, there is generally a liquid market for futures contracts allowing contracts to be quickly netted out. That is, a buyer can sell his futures contract at any time, and a seller can buy back her futures contract at any time. Conversely, because forward markets are generally quite illiquid, traders cannot easily net out their positions. The popularity of the Treasury-bond futures contract has produced liquidity even higher than that on other futures contracts. Positions in that contract can be netted out quite easily.

The above discussion is not intended to be an exhaustive list of differences between the Treasury-bond forward contract and the Treasury-bond futures contract. Rather, it is intended to show that both contracts share fundamental characteristics. Though there are differences, the two instruments should be viewed as variations of the same species, not different species. Thus, the pricing equation of (25.3), which is exact for the forward contract, should be a decent approximation for the futures contract.

Hedging in Interest-Rate Futures

Now that we have the basic institutional details under our belt, we are ready for examples of hedging using either futures contracts or forward contracts on Treasury bonds. Because the T-bond futures contract is extremely popular whereas the forward contract is traded sporadically, our examples use the futures contract.

Example

Ron Cooke owns a mortgage-banking company. On March 1, he made a commitment to loan a total of $1 million to various homeowners on May 1. The loans are 20-year mortgages carrying a 12-percent coupon, the going interest rate on mortgages at the time. Thus, the mortgages are made at par. Though homeowners would not use the term, we could say that he is buying a *forward contract* on a mortgage. That is, he agrees on March 1 to give $1 million to his borrowers on May 1 in exchange for principal and interest from them every month for the next 20 years.

Like many mortgage bankers, he has no intention of paying the $1 million out of his own pocket. Rather, he intends to sell the mortgages to an insurance company. Thus, the insurance company will actually loan the funds and will receive principal and interest over the next 20 years. Mr. Cooke does not currently have an

[12]Futures contracts on bonds are also called *interest-rate futures contracts*.

[13]Delivery occurs two days after the seller notifies the clearinghouse of her intention to deliver.

TABLE 25.4 Effects of Changing Interest Rate on Ron Cooke, Mortgage Banker

Mortgage interest rate on April 15	Above 12%	Below 12%
Sale price to Acme Insurance Company	Below \$1 million (We assume \$940,000)	Above \$1 million (We assume \$1.05 million)
Effect on mortgage banker	He loses because he must loan full \$1 million to borrowers.	He gains because he loans only \$1 million to borrowers.
Dollar gain or loss	Loss of \$60,000 (\$1 million − \$940,000)	Gain of \$50,000 (\$1.05 million − \$1 million)

The interest rate on March 1, the date when the loan agreement was made with the borrowers, was 12 percent. April 15 is the date the mortgages were sold to Acme Insurance Company.

insurance company in mind. He plans to visit the mortgage departments of insurance companies over the next 60 days to sell the mortgages to one or many of them. He sets April 30 as a deadline for making the sale because the borrowers expect the funds on the following day.

Suppose that Mr. Cooke sells the mortgages to the Acme Insurance Co. on April 15. What price will Acme pay for the bonds?

You may think that the insurance company will obviously pay \$1 million for the loans. However, suppose interest rates have risen above 12 percent by April 15. The insurance company will buy the mortgage at a discount. For example, suppose the insurance company agrees to pay only \$940,000 for the mortgages. Because the mortgage banker agreed to loan a full \$1 million to the borrowers, the mortgage banker must come up with the additional \$60,000 (\$1 million − \$940,000) out of his own pocket.

Alternatively, suppose that interest rates fall below 12 percent by April 15. The mortgages can be sold at a premium under this scenario. If the insurance company buys the mortgages at \$1.05 million, the mortgage banker will have made an unexpected profit of \$50,000 (\$1.05 million − \$1 million).

Because Ron Cooke is unable to forecast interest rates, this risk is something that he would like to avoid. The risk is summarized in Table 25.4.

Seeing the interest-rate risk, students at this point may ask, "What does the mortgage banker get out of this loan to offset his risk-bearing?" Mr. Cooke wants to sell the mortgages to the insurance company so that he can get two fees. The first is an *origination fee,* which is paid to the mortgage banker from the insurance company on April 15, that is, on the date the loan is sold. An industry standard in certain locales is 1 percent of the value of the loan, that is \$10,000 (1% × \$1 million). In addition, Mr. Cooke will act as a collection agent for the insurance company. For this service, he will receive a small portion of the outstanding balance of the loan each month. For example, if he is paid 0.03 percent of the loan each month, he will receive \$300 (0.03% × \$1 million) in the first month. As the outstanding balance of the loan declines, he will receive less.

Though Mr. Cooke will earn profitable fees on the loan, he bears interest-rate risk. He loses money if interest rates rise after March 1, and he profits if interest rates fall after March 1. To hedge this risk, he writes June Treasury-bond futures contracts on March 1. As with mortgages, Treasury-bond futures contracts fall in value if interest rates rise. Because he *writes* the contract, he makes money on

TABLE 25.5 Illustration of Hedging Strategy for Ron Cooke, Mortgage Banker

	Cash Markets	Futures Markets
March 1	Mortgage banker makes forward contracts to loan $1 million at 12 percent for 20 years. The loans are to be funded on May 1. No cash changes hands on March 1.	Mortgage banker writes 10 June Treasury-bond futures contracts.
April 15	Loans are sold to Acme Insurance Company. Mortgage banker will receive sale price from Acme on the May 1 funding date.	Mortgage banker buys back all the futures contracts.
If interest rates rise:	Loans are sold at a price below $1 million. Mortgage banker *loses* because he receives less than the $1 million he must give to borrowers.	Each futures contract is bought back at a price below the sales price, resulting in *profit.* Mortgage banker's profit in futures market offsets loss in cash market.
If interest rates fall:	Loans are sold at a price above $1 million. Mortgage banker *gains* because he receives more than the $1 million he must give to borrowers.	Each futures contract is bought back at a price above the sales price, resulting in *loss.* Mortgage banker's loss in futures market offsets gain in cash market.

these contracts if they fall in value. Therefore, with an interest-rate rise, the loss he endures in the mortgages is offset by the gain he earns in the futures market. Conversely, Treasury-bond futures contracts rise in value if interest rates fall. Because he writes the contracts, he suffers losses on them when rates fall. With an interest-rate fall, the profit he makes on the mortgages is offset by the loss he suffers in the futures markets.

The details of this hedging transaction are presented in Table 25.5. The column on the left is labeled "Cash markets," because the deal in the mortgage market is transacted off an exchange. The column on the right shows the offsetting transactions in the futures market. Consider the first row. The mortgage banker enters into a forward contract on March 1. He simultaneously writes Treasury-bond futures contracts. Ten contracts are written because the deliverable instrument on each contract is $100,000 of Treasury bonds. The total is $1 million (10 × $100,000), which is equal to the value of the mortgages. Mr. Cooke would prefer to write May Treasury-bond futures contracts. Here, Treasury bonds would be delivered on the futures contract during the same month that the loan is funded. Because there is no May T-bond futures contract, Mr. Cooke achieves the closest match through a June contract.

If held to maturity, the June contract would obligate the mortgage banker to deliver Treasury bonds in June. Interest-rate risk ends in the cash market when the loans are sold. Interest-rate risk must be terminated in the futures market at that time. Thus, Mr. Cooke nets out his position in the futures contract as soon as the loan is sold to Acme Insurance.

Risk is clearly reduced via an offsetting transaction in the futures market. However, is risk totally eliminated? Risk would be totally eliminated if losses in the cash markets were *exactly* offset in the futures markets and vice versa. This is unlikely to happen because mortgages and Treasury bonds are not identical instruments. First, mortgages may have different maturities than Treasury bonds. Second, Treasury bonds have a different payment stream than do mortgages. Principal is only paid at maturity on T-bonds, whereas principal is paid every month on mortgages. Because mortgages pay principal continuously, these instruments have a shorter *effective* time to maturity than do Treasury bonds of equal maturity.[14] Third, mortgages have default risk whereas Treasury bonds do not. The term structure applicable to instruments with default risk may change even when the term structure for risk-free assets remains constant. Fourth, mortgages may be paid off early and hence have a shorter *expected maturity* than Treasury bonds of equal maturity.

Because mortgages and Treasury bonds are not identical instruments, they are not identically affected by interest rates. If Treasury bonds are less volatile than mortgages, financial consultants may advise Mr. Cooke to write more than 10 T-bond futures contracts. Conversely, if these bonds are more volatile, the consultant may state that less than 10 futures contracts are indicated. An optimal ratio of futures to mortgages will reduce risk as much as possible. However, because the price movements of mortgages and Treasury bonds are not *perfectly correlated,* Mr. Cooke's hedging strategy cannot eliminate all risk.

The above strategy is called a *short hedge* because Mr. Cooke sells futures contracts in order to reduce risk. Though it involves an interest-rate futures contract, this short hedge is analogous to short hedges in agricultural and metallurgical futures contracts. We argued at the beginning of this chapter that individuals and firms institute short hedges to offset inventory price fluctuation. Once Mr. Cooke makes a contract to loan money to borrowers, the mortgages effectively become his inventory. He writes a futures contract to offset the price fluctuation of his inventory.

We now consider an example where a mortgage banker institutes a long hedge.

Example

Margaret Boswell is another mortgage banker. Her firm faces problems similar to those facing Mr. Cooke's firm. However, she tackles the problems through the use of **advance commitments,** a strategy the opposite of Mr. Cooke's. That is, she promises to deliver loans to a financial institution *before* she lines up borrowers. On March 1, her firm agreed to sell mortgages to No-State Insurance Co. The agreement specifies that she must turn over 12-percent coupon mortgages with a face value of $1 million to No-State by May 1. No-State is buying the mortgages at par, implying that they will pay Ms. Boswell $1 million on May 1. As of March 1, Ms. Boswell had not signed up any borrowers. Over the next two months, she will seek out individuals who want mortgages beginning May 1.

As with Mr. Cooke, changing interest rates will affect Ms. Boswell. If interest rates fall before she signs up a borrower, the borrower will demand a premium on a 12-percent coupon loan. That is, the borrower will receive more than par on May 1.[15] Because Ms. Boswell receives par from the insurance company, she must make up the difference.

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[14]Alternatively, we can say that mortgages have shorter duration than do Treasury bonds of equal maturity. A precise definition of duration is provided later in this chapter.

[15]Alternatively, the mortgage would still be at par if a coupon rate below 12 percent were used. However, this is not done since the insurance company only wants to buy 12-percent mortgages.

TABLE 25.6 Illustration of Advance Commitment for Margaret Boswell, Mortgage Banker

	Cash Markets	Futures Markets
March 1	Mortgage banker makes a forward contract (advance commitment) to deliver $1 million of mortgages to No-State Insurance. The insurance company will pay par to Ms. Boswell for the loans on May 1. The borrowers are to receive their funding from mortgage banker on May 1. The mortgages are to be 12-percent coupon loans for 20 years.	Mortgage banker buys 10 June Treasury-bond futures contracts.
April 15	Mortgage banker signs up borrowers to 12-percent coupon, 20-year mortgages. She promises that the borrowers will receive funds on May 1.	Mortgage banker sells all futures contracts.
If interest rates rise:	Mortgage banker issues mortgages to borrowers at a discount. Mortgage banker *gains* because she receives par from insurance company.	Futures contract is sold at a price below purchase price, resulting in *loss.* Mortgage banker's loss in futures market offsets gain in cash market.
If interest rates fall:	Loans to borrowers are issued at a premium. Mortgage banker *loses* because she receives only par from insurance company.	Futures contract is sold at a price above purchase price, resulting in *gain.* Mortgage banker's gain in futures market offsets loss in cash market.

Conversely, if interest rates rise, a 12-percent coupon loan will be made at a discount. That is, the borrower will receive less than par on May 1. Because Ms. Boswell receives par from the insurance company, the difference is pure profit to her.

The details are provided in the left-hand column of Table 25.6. As did Mr. Cooke, Ms. Boswell finds the risk burdensome. Therefore, she offsets her advance commitment with a transaction in the futures markets. Because she *loses* in the cash market when interest rates fall, she *buys* futures contracts to reduce the risk. When interest rates fall, the value of her futures contracts increases. The gain in the futures market offsets the loss in the cash market. Conversely, she gains in the cash markets when interest rates rise. The value of her futures contracts decreases when interest rates rise, offsetting her gain.

We call this a *long hedge* because Ms. Boswell offsets risk in the cash markets by buying a futures contract. Though it involves an interest-rate futures contract, this long hedge is analogous to long hedges in agricultural and metallurgical futures contracts. We argued at the beginning of this chapter that individuals and firms institute long hedges when their finished goods are to be sold at a fixed price. Once Ms. Boswell makes the advance commitment with No-State Insurance, she has fixed her sales price. She buys a futures contract to offset the price fluctuation of her raw materials, that is, her mortgages.

CONCEPT QUESTIONS ?

- How are forward contracts on bonds priced?
- What are the differences between forward contracts on bonds and futures contracts on bonds?
- Give examples of hedging with futures contracts on bonds.

25.5 DURATION HEDGING

The last section concerned the risk of interest-rate changes. We now want to explore this risk in a more precise manner. In particular, we want to show that the concept of duration is a prime determinant of interest-rate risk. We begin by considering the effect of interest-rate movements on bond prices.

The Case of Zero-Coupon Bonds

Imagine a world where the interest rate is 10 percent across all maturities. A one-year pure discount bond pays $110 at maturity. A five-year pure discount bond pays $161.05 at maturity. Both of these bonds are worth $100, as given by[16]

Value of One-Year Pure Discount Bond:

$$\$100 = \frac{\$110}{1.10}$$

Value of Five-Year Pure Discount Bond:

$$\$100 = \frac{\$161.05}{(1.10)^5}$$

Which bond will change more when interest rates move? To find out, we calculate the value of these bonds when interest rates are either 8 or 12 percent. The results are presented in Table 25.7. As can be seen, the five-year bond has greater price swings than does the one-year bond. That is, both bonds are worth $100 when interest rates are 10 percent. The five-year bond is worth more than the one-year bond when interest rates are 8 percent and worth less than the one-year bond when interest rates are 12 percent. We state that the five-year bond is subject to more price volatility. This point, which was mentioned in passing in an earlier section of the chapter, is not difficult to understand. The interest-rate term in the denominator, $1 + r$, is taken to the fifth power for a five-year bond and only to the first power for the one-year bond. Thus, the effect of a changing interest rate is magnified for the five-year bond. The general rule is

> The percentage price changes in long-term pure discount bonds are greater than the percentage price changes in short-term pure discount bonds.

The Case of Two Bonds with the Same Maturity but with Different Coupons

The previous example concerned pure discount bonds of different maturities. We now want to see the effect of different coupons on price volatility. To abstract from the effect of differing maturities, we consider two bonds with the same maturity but with different coupons.

[16]Alternatively, we could have chosen bonds that pay $100 at maturity. Their values would be $90.91 ($100/1.10) and $62.09 [$100/(1.10)^5]. However, our comparisons to come are made easier if both have the same initial price.

TABLE 25.7 Value of a Pure Discount Bond as a Function of Interest Rate

Interest Rate	One-Year Pure Discount Bond	Five-Year Pure Discount Bond
8%	$\$101.85 = \frac{\$110}{1.08}$	$\$109.61 = \frac{\$161.05}{(1.08)^5}$
10%	$\$100.00 = \frac{\$110}{1.10}$	$\$100.00 = \frac{\$161.05}{(1.10)^5}$
12%	$98.21 = \frac{\$110}{1.12}$	$\$91.38 = \frac{\$161.05}{(1.12)^5}$

For a given interest rate change, a five-year pure discount bond fluctuates more in price than does a one-year pure discount bond.

Consider a five-year, 10-percent coupon bond and a five-year, 1-percent coupon bond. When interest rates are 10 percent, the bonds are priced at

Value of Five-Year, 10-Percent Coupon Bond:

$$\$100 = \frac{\$10}{1.10} + \frac{\$10}{(1.10)^2} + \frac{\$10}{(1.10)^3} + \frac{\$10}{(1.10)^4} + \frac{\$110}{(1.10)^5}$$

Value of Five-Year, 1-Percent Coupon Bond:

$$\$65.88 = \frac{\$1}{1.10} + \frac{\$1}{(1.10)^2} + \frac{\$1}{(1.10)^3} + \frac{\$1}{(1.10)^4} + \frac{\$101}{(1.10)^5}$$

Which bond will change more in *percentage terms* if interest rates change?[17] To find out, we first calculate the value of these bonds when interest rates are either 8 or 12 percent. The results are presented in Table 25.8. As we would expect, the 10-percent coupon bond always sells for more than the 1-percent coupon bond. Also, as we would expect, each bond is worth more when the interest rate is 8 percent than when the interest rate is 12 percent.

We calculate percentage price changes for both bonds as the interest rate changes from 10 to 8 percent and from 10 to 12 percent. These percentage price changes are

	10% Coupon Bond	1% Coupon Bond
Interest rate changes from 10% to 8%:	$7.99\% = \frac{\$107.99}{\$100} - 1$	$9.37\% = \frac{\$72.05}{\$65.88} - 1$
Interest rate changes from 10% to 12%:	$-7.21\% = \frac{\$92.79}{\$100} - 1$	$-8.39\% = \frac{\$60.35}{\$65.88} - 1$

As can be seen, the 1-percent coupon bond has a greater percentage price increase than does the 10-percent coupon bond when the interest rate falls. Similarly, the 1-percent coupon bond has a greater percentage price decrease than does the 10-percent coupon bond when the interest rate rises. Thus, we say that the percentage price changes on the 1-percent coupon bond are greater than are the percentage price changes on the 10-percent coupon bond.

[17]The bonds are at different prices initially. Thus, we are concerned with percentage price changes, not absolute price changes.

TABLE 25.8 Value of Coupon Bonds at Different Interest Rates

Interest Rate	Five-Year, 10% Coupon Bond
8%	$\$107.99 = \frac{\$10}{1.08} + \frac{\$10}{(1.08)^2} + \frac{\$10}{(1.08)^3} + \frac{\$10}{(\$1.08)^4} + \frac{\$110}{(1.08)^5}$
10%	$\$100.00 = \frac{\$10}{1.10} + \frac{\$10}{(1.10)^2} + \frac{\$10}{(1.10)^3} + \frac{\$10}{(1.10)^4} + \frac{\$110}{(1.10)^5}$
12%	$92.79 = \frac{\$10}{1.12} + \frac{\$10}{(1.12)^2} + \frac{\$10}{(1.12)^3} + \frac{\$10}{(1.12)^4} + \frac{\$110}{(1.12)^5}$
Interest Rate	**Five-Year, 1% Coupon Bond**
8%	$\$72.05 = \frac{\$1}{1.08} + \frac{\$1}{(1.08)^2} + \frac{\$1}{(1.08)^3} + \frac{\$1}{(1.08)^4} + \frac{\$101}{(1.08)^5}$
10%	$\$65.88 = \frac{\$1}{1.10} + \frac{\$1}{(1.10)^2} + \frac{\$1}{(1.10)^3} + \frac{\$1}{(1.10)^4} + \frac{\$101}{(1.10)^5}$
12%	$\$60.35 = \frac{\$1}{1.12} + \frac{\$1}{(1.12)^2} + \frac{\$1}{(1.12)^3} + \frac{\$1}{(1.12)^4} + \frac{\$101}{(1.12)^5}$

Duration

The question, of course, is "Why?" We can answer this question only after we have explored a concept called **duration.** We begin by noticing that any coupon bond is actually a combination of pure discount bonds. For example, the five-year, 10-percent coupon bond is made up of five pure discount bonds:

1. A pure discount bond paying $10 at the end of year 1.
2. A pure discount bond paying $10 at the end of year 2.
3. A pure discount bond paying $10 at the end of year 3.
4. A pure discount bond paying $10 at the end of year 4.
5. A pure discount bond paying $110 at the end of year 5.

Similarly, the five-year, 1-percent coupon bond is made up of five pure discount bonds. Because the price volatility of a pure discount bond is determined by its maturity, we would like to determine the average maturity of the five pure discount bonds that make up a five-year coupon bond. This leads us to the concept of duration.

We calculate average maturity in three steps. For the 10-percent coupon bond, we have these:

1. *Calculate Present Value of Each Payment.* We do this as

Year	Payment	Present Value of Payment by Discounting at 10%
1	$ 10	$ 9.091
2	10	8.264
3	10	7.513
4	10	6.830
5	110	68.302
		$100.00

2. *Express the Present Value of Each Payment in Relative Terms.* We calculate the relative value of a single payment as the ratio of the present value of the payment to the value of the bond. The value of the bond is $100. We have

Year	Payment	Present Value of Payment	Relative Value = Present Value of Payment / Value of Bond
1	$ 10	$ 9.091	$9.091/$100 = 0.09091
2	10	8.264	0.08264
3	10	7.513	0.07513
4	10	6.830	0.06830
5	110	68.302	0.68302
		$100.00	1.0

The bulk of the relative value, 68.302 percent, occurs at year 5 because the principal is paid back at that time.

3. *Weight the Maturity of Each Payment by Its Relative Value.* We have

$$4.1699 \text{ years} = 1 \text{ year} \times 0.09091 + 2 \text{ years} \times 0.08264 + 3 \text{ years} \times 0.07513 + 4 \text{ years} \times 0.06830 + 5 \text{ years} \times 0.68302$$

There are many ways to calculate the average maturity of a bond. We have calculated it by weighting the maturity of each payment by the payment's present value. We find that the *effective* maturity of the bond is 4.1699 years. *Duration* is a commonly used word for effective maturity. Thus, the bond's duration is 4.1699 years. Note that duration is expressed in units of time.[18]

Because the five-year, 10-percent coupon bond has a duration of 4.1699 years, its percentage price fluctuations should be the same as those of a zero-coupon bond with a duration of 4.1699 years.[19] It turns out that the five-year, 1-percent coupon bond has a duration of 4.8742 years. Because the 1-percent coupon bond has a higher duration than the 10-percent bond, the 1-percent coupon bond should be subject to greater price fluctuations. This is exactly what we found earlier. In general, we say:

> The percentage price changes of a bond with high duration are greater than the percentage price changes of a bond with low duration.

A final question: Why *does* the 1-percent bond have a greater duration than the 10-percent bond, even though they both have the same five-year maturity? As mentioned earlier, duration is an average of the maturity of the bond's cash flows, weighted by the present

[18]The mathematical formula for duration is

$$\text{Duration} = \frac{\text{PV}(C_1)1 + \text{PV}(C_2)2 + \ldots + \text{PV}(C_T)T}{\text{PV}}$$

and

$$\text{PV} = \text{PV}(C_1) + \text{PV}(C_2) + \ldots + \text{PV}(C_T)$$

$$\text{PV}(C_T) = \frac{C_T}{(1+r)^T}$$

where C_T is the cash to be received in time T and r is the current discount rate.

Also note that in the above numerical example we discounted each payment by the interest rate of 10 percent. This was done because we wanted to calculate the duration of the bond before a change in the interest rate occurred. After a change in the rate to, say, 8 or 12 percent, all three of our steps would need to reflect the new interest rate. In other words, the duration of a bond is a function of the current interest rate.

[19]Actually, this relationship only exactly holds in the case of a one-time shift in a flat yield curve, where the change in the spot rate is identical for all different maturities.

value of each cash flow. The 1-percent coupon bond receives only $1 in each of the first four years. Thus, the weights applied to years 1 through 4 in the duration formula will be low. Conversely, the 10-percent coupon bond receives $10 in each of the first four years. The weights applied to years 1 through 4 in the duration formula will be higher.

Matching Liabilities with Assets

Earlier in this chapter we argued that firms can hedge risk by trading in futures. Because some firms are subject to interest-rate risk, we showed how they can hedge with interest-rate futures contracts. Firms may also hedge interest-rate risk by matching liabilities with assets. This ability to hedge follows from our discussion of duration.

Example

The Physical Bank of New York has the following market-value balance sheet:

PHYSICAL BANK OF NEW YORK
Market-Value Balance Sheet

	Market Value	Duration
Assets		
Overnight money	$ 35 million	0
Accounts-receivable–backed loans	500 million	3 months
Inventory loans	275 million	6 months
Industrial loans	40 million	2 years
Mortgages	150 million	14.8 years
	$1,000 million	
Liabilities and Owners' Equity		
Checking and savings accounts	$ 400 million	0
Certificates of deposit	300 million	1 year
Long-term financing	200 million	10 years
Equity	100 million	
	$1,000 million	

The bank has $1,000 million of assets and $900 million of liabilities. Its equity is the difference between the two: $100 million ($1,000 million − $900 million). Both the market value and the duration of each individual item is provided in the balance sheet. Both overnight money and checking and savings accounts have a duration of zero. This is because the interest paid on these instruments adjusts immediately to changing interest rates in the economy.

The bank's managers think that interest rates are likely to move quickly in the coming months. Because they do not know the direction of the movement, they are worried that their bank is vulnerable to changing rates. They call in a consultant, James Charest, to determine hedging strategy.

Mr. Charest first calculates the duration of the assets and the duration of the liabilities.[20]

[20]Note that the duration of a group of items is an average of the duration of the individual items, weighted by the market value of each item. This is a simplifying step that greatly increases duration's practicality.

Duration of Assets:

$$2.56 \text{ years} = 0 \text{ years} \times \frac{\$35 \text{ million}}{\$1{,}000 \text{ million}} + \tfrac{1}{4} \text{ year} \times \frac{\$500 \text{ million}}{\$1{,}000 \text{ million}} + \tfrac{1}{2} \text{ year} \times \frac{\$275 \text{ million}}{\$1{,}000 \text{ million}} + 2 \text{ years} \times \frac{\$40 \text{ million}}{\$1{,}000 \text{ million}} + 14.8 \text{ years} \times \frac{\$150 \text{ million}}{\$1{,}000 \text{ million}} \quad (25.4)$$

Duration of Liabilities:

$$2.56 = 0 \text{ years} \times \frac{\$400 \text{ million}}{\$900 \text{ million}} + 1 \text{ year} \times \frac{\$300 \text{ million}}{\$900 \text{ million}} + 10 \text{ years} \times \frac{\$200 \text{ million}}{\$900 \text{ million}} \quad (25.5)$$

The duration of the assets, 2.56 years, equals the duration of the liabilities. Because of this, Mr. Charest argues that the firm is immune to interest-rate risk.

Just to be on the safe side, the bank calls in a second consultant, Gail Ellert. Ms. Ellert argues that it is incorrect to simply match durations, because assets total $1,000 million and liabilities total only $900 million. If both assets and liabilities have the same duration, the price change on a *dollar* of assets should be equal to the price change on a dollar of liabilities. However, the *total* price change will be greater for assets than for liabilities, because there are more assets than liabilities in this bank. The firm will be immune from interest-rate risk only when the duration of the liabilities is greater than the duration of the assets. Ms. Ellert states that the following relationship must hold if the bank is to be **immunized,** that is, immune to interest-rate risk:

$$\text{Duration of assets} \times \text{Market value of assets} = \text{Duration of liabilities} \times \text{Market value of liabilities} \quad (25.6)$$

She says that the bank should not *equate* the duration of the liabilities with the duration of the assets. Rather, using equation (25.6), the bank should match the duration of the liabilities to the duration of the assets. She suggests two ways to achieve this match.

1. *Increase the Duration of the Liabilities without Changing the Duration of the Assets.* Ms. Ellert argues that the duration of the liabilities could be increased to

$$\text{Duration of assets} \times \frac{\text{Market value of assets}}{\text{Market value of liabilities}} = 2.56 \text{ years} \times \frac{\$1{,}000 \text{ million}}{\$900 \text{ million}} = 2.84 \text{ years}$$

Equation (25.5) then becomes:

$$2.56 \times \$1 \text{ billion} = 2.84 \times \$900 \text{ million}$$

2. *Decrease the Duration of the Assets without Changing the Duration of the Liabilities.* Alternatively, Ms. Ellert points out that the duration of the assets could be decreased to

$$\begin{aligned}&\text{Duration of liabilities} \times \frac{\text{Market value of liabilities}}{\text{Market value of assets}}\\&= 2.56 \text{ years} \times \frac{\$900 \text{ million}}{\$1{,}000 \text{ million}}\\&= 2.30 \text{ years}\end{aligned}$$

Equation (25.6) then becomes:

$$2.30 \times \$1 \text{ billion} = 2.56 \times \$900 \text{ million}$$

Though we agree with Ms. Ellert's analysis, the bank's current mismatch was small anyway. Huge mismatches have occurred for real-world financial institutions, particularly savings and loans. S&Ls have frequently invested large portions of their assets in mortgages. The durations of these mortgages would clearly be above 10 years. Much of the funds available for mortgage lending were financed by short-term credit, especially savings accounts. As we mentioned, the duration of such instruments is quite small. A thrift institution in this situation faces a large amount of interest-rate risk, because any increase in interest rates would greatly reduce the value of the mortgages. Because an interest-rate rise would only reduce the value of the liabilities slightly, the equity of the firm would fall. As interest rates rose over much of the 1960s and the 1970s, many S&Ls found that the market value of their equity approached zero.[21]

Duration and the accompanying immunization strategies are useful in other areas of finance. For example, many firms establish pension funds to meet obligations to retirees. If the assets of a pension fund are invested in bonds and other fixed-income securities, the duration of the assets can be computed. Similarly, the firm views the obligations to retirees as analogous to interest payments on debt. The duration of these liabilities can be calculated as well. The manager of a pension fund would commonly choose pension assets so that the duration of the assets is matched with the duration of the liabilities. In this way, changing interest rates would not affect the net worth of the pension fund.

Life insurance companies receiving premiums today are legally obligated to provide death benefits in the future. Actuaries view these future benefits as analogous to interest and principal payments of fixed-income securities. The duration of these expected benefits can be calculated. Insurance firms frequently invest in bonds where the duration of the bonds is matched to the duration of the future death benefits.

The business of a leasing company is quite simple. The firm issues debt to purchase assets, which are then leased. The lease payments have a duration, as does the debt. Leasing companies frequently structure debt financing so that the duration of the debt matches the duration of the lease. If the firm did not do this, the market value of its equity could be eliminated by a quick change in interest rates.

CONCEPT QUESTIONS ?

- What is duration?
- How is the concept of duration used to reduce interest-rate risk?

[21] Actually, the market value of the equity could easily be negative in this example. However, S&Ls in the real world have an asset not shown on our market-value balance sheet: the ability to generate new, profitable loans. This should increase the market value of a thrift above the market value of its outstanding loans less its existing debt.

25.6 SWAPS CONTRACTS

Swaps are close cousins to forwards and futures contracts. Swaps are arrangements between two counterparts to exchange cash flows over time. There is enormous flexibility in the forms that swaps can take, but the two basic types are **interest-rate swaps** or **currency swaps.** Often these are combined when interest received in one currency is swapped for interest in another currency.

Interest-Rate Swaps

Like other derivatives, swaps are tools that firms can use to easily change their risk exposures and their balance sheets.[22] Consider a firm that has borrowed and carried on its books an obligation to repay a 10-year loan for $100 million of principal with a 9-percent coupon rate paid annually. Ignoring the possibility of calling the loan, the firm expects to have to pay coupons of $9 million every year for 10 years and a balloon payment of $100 million at the end of the 10 years. Suppose, though, that the firm is uncomfortable with having this large fixed obligation on its books. Perhaps the firm is in a cyclical business where its revenues vary and could, conceivably, fall to a point where it would be difficult to make the debt payment.

Suppose, too, that the firm earns a lot of its revenue from financing the purchase of its products. Typically, for example, a manufacturer might help its customers finance their purchase of its products through a leasing or credit subsidiary. Usually these loans are for relatively short time periods and are financed at some premium over the prevailing short-term rate of interest. This puts the firm in the position of having revenues that move up and down with interest rates while its costs are relatively fixed.

This is a classic situation where a swap can be used to offset the risk. When interest rates rise, the firm would have to pay more on the loan, but it would be making more on its product financing. What the firm would really prefer is to have a floating-rate loan rather than a fixed-rate loan. It can use a swap to accomplish this.

Of course, the firm could also just go into the capital markets and borrow $100 million at a variable interest rate and then use the proceeds to retire its outstanding fixed-rate loan. While this is possible, it is generally quite expensive, requiring underwriting a new loan and the repurchase of the existing loan. The ease of entering into a swap is its inherent advantage.

The particular swap would be one that exchanged its fixed obligation for an agreement to pay a floating rate. Every six months it would agree to pay a coupon based on whatever the prevailing interest rate was at the time in exchange for an agreement from a counterparty to pay the firm's fixed coupon.

A common reference point for floating-rate commitments is called LIBOR. LIBOR stands for the London Interbank Offered Rate, and it is the rate that most international banks charge one another for dollar-denominated loans in the London market. LIBOR is commonly used as the reference rate for a floating-rate commitment, and, depending on the creditworthiness of the borrower, the rate can vary from LIBOR to LIBOR plus one point or more over LIBOR.

If we assume that our firm has a credit rating that requires it to pay LIBOR plus 50 basis points, then in a swap it would be exchanging its fixed 9-percent obligation for the obligation to pay whatever the prevailing LIBOR rate is plus 50 basis points. Figure 25.2 displays how the cash flows on this swap would work. In the figure we have assumed that LIBOR starts at 8 percent and rises for four years to 11 percent and then drops to 7 percent. As the figure

[22]Under current accounting rules, most derivatives do not usually show up on firms' balance sheets since they do not have an historical cost (i.e., the amount a dealer would pay on the initial transaction day).

FIGURE 25.2 Fixed-for-Floating a Swap: Cash Flows ($ million)

	Coupons										
	Year	1	2	3	4	5	6	7	8	9	10
A. Swap											
Fixed obligation	9	9	9	9	9	9	9	9	9	9	9
LIBOR floating	−8.5	−9.5	−10.5	−11.5	−7.5	−7.5	−7.5	−7.5	−7.5	−7.5	−7.5
B. Original Loan											
Fixed obligation	−9	−9	−9	−9	−9	−9	−9	−9	−9	−9	109
Net effect	−8.5	−9.5	10.5	11.5	7.5	7.5	7.5	7.5	7.5	7.5	−107.5

illustrates, the firm would owe a coupon of 8.5% × $100 million = $8.5 million in year 1, $9.5 million in year 2, $10.5 million in year 3, and $11.5 million in year 4. The precipitous drop to 7 percent lowers the annual payments to $7.5 million thereafter. In return, the firm receives the fixed payment of $9 million each year. Actually, rather than swapping the full payments, the cash flows would be netted. Since the firm is paying variable and receiving fixed—which it uses to pay its lender—in the first year, for example, the firm owes $8.5 million and is owed by its counterparty, who is paying fixed, $9 million. Hence, net, the firm would receive a payment of $.5 million. Since the firm has to pay its lender $9 million, but gets a net payment from the swap of $.5 million, it really only pays out the difference, or $8.5 million. In each year, then, the firm would effectively pay only LIBOR plus 50 basis points.

Notice, too, that the entire transaction can be carried out without any need to change the terms of the original loan. In effect, by swapping, the firm has found a counterparty who is willing to pay its fixed obligation in return for the firm paying a floating obligation.

Currency Swaps

FX stands for foreign exchange, and currency swaps are sometimes called FX swaps. Currency swaps are swaps of obligations to pay cash flows in one currency for obligations to pay in another currency.

Currency swaps arise as a natural vehicle for hedging the risk in international trade. For example, suppose a U.S. firm sells a broad range of its product line in the German market. Every year the firm can count on receiving revenue from Germany in the German currency, Deutschemarks, or DM for short. We will study international finance later in this book, but for now we can just observe that, because exchange rates fluctuate, this subjects the firm to considerable risk.

If the firm produces its products in the United States and exports them to Germany, then the firm has to pay its workers and its suppliers in dollars. But, it is receiving some of its revenues in DM. The exchange rate between $ and DM changes over time. As the DM rises in value, the German revenues are worth more $, but as it falls they decline. Suppose that the firm can count on selling 100 million DM of goods each year in Germany. If the exchange rate is 2 DM for each $, then the firm will receive $50 million. But, if the exchange rate were to rise to 3 DM for each $, the firm would only receive $33.333 million for its 100 million DM. Naturally the firm would like to protect itself against these currency swings.

To do so the firm can enter into a currency swap. We will learn more about exactly what the terms of such a swap might be, but for now we can assume that the swap is for five years at a fixed term of 100 million DM for $50 million each year. Now, no matter what happens to the exchange rate between DM and $ over the next five years, as long as the firm makes 100 million DM each year from the sale of its products, it will swap this for $50 million each year.

We have not addressed the question of how the market sets prices for swaps, either interest-rate swaps or currency swaps. In the fixed-for-floating example and in the currency swap, we just quoted some terms. We won't go into great detail on exactly how it is done, but we can stress the most important points.

Swaps, like forwards and futures, are essentially zero-sum transactions, which is to say that in both cases the market sets prices at a fair level, and neither party has any substantial bargain or loss at the moment the deal is struck. For example, in the currency swap, the swap rate is some average of the market expectation of what the exchange rate will be over the life of the swap. In the interest-rate swap, the rates are set as the fair floating and fixed rates for the creditor, taking into account the creditworthiness of the counterparties. We can actually price swaps fairly once we know how to price forward contracts. In our interest-rate swap example, the firm swapped LIBOR plus 50 basis points for a 9-percent fixed rate, all on a principal amount of $100 million. This is equivalent to a series of forward contracts extending out the life of the swap. In year 1, for example, having made the swap, the firm is in the same position that it would be if it had sold a forward contract entitling the buyer to receive LIBOR plus 50 basis points on $100 million in return for a fixed payment of $9 million (9 percent on $100 million). Similarly, the currency swap can also be viewed as a series of forward contracts.

CONCEPT QUESTION ?

- Show that a currency swap is equivalent to a series of forward contracts.

Exotics

Up to now we have dealt with the meat and potatoes of the derivatives markets, swaps, options, forwards, and futures. **Exotics** are the complicated blends of these that often produce the surprising results for the buyers.

One of the more interesting types of exotics is called an *inverse floater.* In our fixed-for-floating swap, the floating payments fluctuated with LIBOR. An inverse floater is one that fluctuates inversely with some rate such as LIBOR. For example, the floater might pay an interest rate of 20 percent minus LIBOR. IF LIBOR is 9 percent, then the inverse pays 11 percent, and if LIBOR rises to 12 percent, the payments on the inverse would fall to 8 percent. Clearly the purchaser of an inverse profits from the inverse if interest rates fall.

Both floaters and inverse floaters have a supercharged version called *superfloaters* and *superinverses* that fluctuate more than one for one with movements in interest rates. As an example of a superinverse floater, consider a floater that pays an interest rate of 30 percent minus *twice* LIBOR. When LIBOR is 10 percent, the inverse pays

$$30\% - 2 \times 10\% = 30\% - 20\% = 10\%$$

and if LIBOR falls by 3 percent to 7 percent, then the return on the inverse rises by 6 percent from 10 percent to 16 percent,

$$30\% - 2 \times 7\% = 30\% - 14\% = 16\%$$

Sometimes derivatives are combined with options to bound the impact of interest rates. The most important of these instruments are called *caps* and *floors.* A cap is so named because it puts an upper limit or a cap on the impact of a rise in interest rates. A floor, conversely, provides a floor below which the interest rate impact is insulated.

To illustrate the impact of these, consider a firm that is borrowing short-term and is concerned that interest rates might rise. For example, using LIBOR as the reference interest rate, the firm might purchase a 7 percent cap. The cap pays the firm the difference between LIBOR and 7 percent on some principal amount, provided that LIBOR is greater than 7 percent. As long as LIBOR is below 7 percent, the holder of the cap receives no payments.

By purchasing the cap the firm has assured itself that even if interest rates rise above 7 percent, it will not have to pay more than a 7 percent rate. Suppose that interest rates rise to 9 percent. While the firm is borrowing short-term and paying 9 percent rates, this is offset by the cap, which is paying the firm the difference between 9 percent and the 7 percent limit. For any LIBOR rate above 7 percent, the firm receives the difference between LIBOR and 7 percent, and, as a consequence, it has capped its cost of borrowing at 7 percent.

On the other side, consider a financial firm that is in the business of lending short-term and is concerned that interest rates—and, consequently, its revenues—might fall. The firm could purchase a floor to protect itself from such declines. If the limit on the floor is 7 percent, then the floor pays the difference between 7 percent and LIBOR whenever LIBOR is below 7 percent, and nothing if LIBOR is above 7 percent. Thus, if interest rates were to fall to, say, 5 percent while the firm is only receiving 5 percent from its lending activities, the floor is paying it the difference between 7 percent and 5 percent, or an additional 2 percent. By purchasing the floor, the firm has assured itself of receiving no less than 7 percent from the combination of the floor and its lending activities.

We have only scratched the surface of what is available in the world of derivatives. Derivatives are designed to meet marketplace needs, and the only binding limitation is the human imagination. Nowhere should the buyer's warning *caveat emptor* be taken more seriously than in the derivatives markets, and this is especially true for the exotics. If swaps are the meat and potatoes of the derivatives markets, then caps and floors are the meat and potatoes of the exotics. As we have seen, they have obvious value as hedging instruments. But, much attention has been focused on truly exotic derivatives, some of which appear to have arisen more as the residuals that were left over from more straightforward deals. We won't examine these in any detail, but suffice it to say that some of these are so volatile and unpredictable that market participants have dubbed them "toxic waste."

25.7 Actual Use of Derivatives

Because derivatives do not usually appear in financial statements, it is much more difficult to observe the use of derivatives by firms when compared to, say, bank debt. Much of our knowledge of corporate derivative use comes from academic surveys. Most surveys report that the use of derivatives appears to vary widespread among large publically traded firms. It appears that about one-half of all publically traded nonfinancial firms use derivatives of some kind.[23] Large firms are far more likely to use derivatives than small firms. Table 25.9 shows that for firms that use derivatives, foreign-currency and interest-rate derivatives are the most frequently used.[24]

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[23]Gordon M. Bodnar, Gregory S. Hayt, and Richard Marston, "1998 Wharton Survey of Finance Risk Management by U.S. Non-Financial Firms," *Financial Management* (Winter 1998).

[24]Howton and Perfect report that interest rate derivatives are the most frequently used derivatives. Shawn D. Howton and Steven B. Perfect, "Currency and Interest-Rate Derivatives Use in U.S. Firms," *Financial Management* (Winter 1998).

TABLE 25.9 Derivative Usage by Firms Using Derivatives

	Exposure Managed with Derivatives	Exposure Not Managed with Derivatives
Foreign exchange	88%	12%
Interest rate	77%	23%
Commodity	55%	45%
Equity	30%	70%

Source: Gordon M. Bodnar, Gregory S. Hayt, and Richard Marston, "1998 Wharton Survey of Financial Risk Management of U.S. Non-Financial Firms," *Financial Management* (Winter 1998). Survey included 400 firms; 50 percent of the firms reported using derivatives.

The prevailing view is that derivatives can be very helpful in reducing the variability of firm cash flows, which, in turn, reduces the various costs associated with financial distress. Therefore, it is somewhat puzzling that large firms use derivatives more often than small firms—because large firms tend to have less cash flow variability than small firms. Also some surveys report that firms occasionally use derivatives when they want to speculate about future prices and not just to hedge risks.[25]

However, most of the evidence is consistent with the theory that derivatives are most frequently used by firms where financial distress costs are high and access to the capital markets is constrained.[26]

25.8 SUMMARY AND CONCLUSIONS

1. Firms hedge to reduce risk. This chapter shows a number of hedging strategies.
2. A forward contract is an agreement by two parties to sell an item for cash at a later date. The price is set at the time the agreement is signed. However, cash changes hands on the date of delivery. Forward contracts are generally not traded on organized exchanges.
3. Futures contracts are also agreements for future delivery. They have certain advantages, such as liquidity, that forward contracts do not. An unusual feature of futures contracts is the mark-to-the-market convention. If the price of a futures contract falls on a particular day, every buyer of the contract must pay money to the clearinghouse. Every seller of the contract receives money from the clearinghouse. Everything is reversed if the price rises. The mark-to-the-market convention prevents defaults on futures contracts.
4. We divided hedges into two types: short hedges and long hedges. An individual or firm that sells a futures contract to reduce risk is instituting a short hedge. Short hedges are generally appropriate for holders of inventory. An individual or firm that buys a futures contract to

[25]Walter Dolde, "The Trajectory of Corporate Financial Risk Management," *Journal of Applied Corporate Finance* (Fall 1993).

[26]Shawn D. Howton and Steven B. Perfect, "Currency and Interest-Rate Derivatives Use in U.S. Firms," *Financial Management* (Winter 1998). See also H. Berkman and M. E. Bradbury, "Empirical Evidence on the Corporate Use of Derivatives," *Financial Management* (Summer 1996).

reduce risk is instituting a long hedge. Long hedges are typically used by firms with contracts to sell finished goods at a fixed price.

5. An interest-rate futures contract employs a bond as the deliverable instrument. Because of their popularity, we worked with Treasury-bond futures contracts. We showed that Treasury-bond futures contracts can be priced using the same type of net-present-value analysis that is used to price Treasury bonds themselves.
6. Many firms are faced with interest-rate risk. They can reduce this risk by hedging with interest-rate futures contracts. As with other commodities, a short hedge involves the sale of a futures contract. Firms that are committed to buying mortgages or other bonds are likely to institute short hedges. A long hedge involves the purchase of a futures contract. Firms that have agreed to sell mortgages or other bonds at a fixed price are likely to institute long hedges.
7. Duration measures the average maturity of all the cash flows in a bond. Bonds with high duration have high price variability. Firms frequently try to match the duration of their assets with the duration of their liabilities.
8. Swaps are agreements to exchange cash flows over time. The first major type is an interest-rate swap in which one pattern of coupon payments, say, fixed payments, is exchanged for another, say, coupons that float with LIBOR. The second major type is a currency swap in which an agreement is struck to swap payments denominated in one currency for payments in another currency over time.

Key Terms

Advance commitments 712
Cash transaction 697
Currency swaps 721
Deliverable instrument 696
Duration 716
Exotics 723
Forward contract 696
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Hedging 696
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Long hedge 704
Making delivery 696
Marked to the market 698
Short hedge 703
Speculating 696
Swaps 721
Taking delivery 696

Suggested Readings

Several cases that illustrate the concepts, tools, and markets for hedging can be found in

Tufano, Peter. "How Financial Engineering Can Advance Corporate Strategy." *Harvard Business Review* (January–February 1996).

An advanced article on the empirical implications of very recent models for pricing swaps contracts is in

Minton, Bernadette A. "An Empirical Examination of Basic Valuation Models for Plain Vanilla U.S. Interest Rate Swaps." *Journal of Financial Economics* 44 (Winter 1997).

Questions and Problems

Futures and Forward Contracts

25.1 Define:

a. Forward contract

b. Futures contract

25.2 Explain the three ways in which futures contracts and forward contracts differ.

25.3 The following table lists the closing prices for wheat futures contracts. Suppose you bought one contract at \$5.00 at the opening of trade on March 15.

March 15	\$5.03
March 16	\$5.08
March 17	\$5.12
March 18	\$5.10
March 19	\$4.98

a. Suppose that on March 18 you receive from your broker a notice of delivery on that day.
  i. What is the delivery price?
  ii. What price did you pay for wheat?
  iii. List the cash flows associated with this contract.

b. Suppose that on March 19 you receive from your broker a notice of delivery on that day.
  i. What is the delivery price?
  ii. What price did you pay for wheat?
  iii. List the cash flows associated with this contract.

25.4 Two days ago, you agreed to buy a 10-year, zero-coupon bond that would be issued in a year. Today, both the 1-year and 11-year spot rates unexpectedly shifted downward an equal amount. What should today's price of the forward contract be?

25.5 *a.* How is a short hedge created?
b. In what type of situation is a short hedge a wise strategy?
c. How is a long hedge created?
d. In what type of situation is a long hedge a wise strategy?

25.6 A speculator is an investor who uses his or her private information to profit from futures contracts. Mary Johnson is a speculator, who believes that wheat futures prices will fall in a month. What position would Mary Johnson take?

25.7 A classmate of yours recently entered the import/export business. During a visit with him last week, he said to you, "If you play the game right, this is the safest business in the world. By hedging all my transactions in the foreign-exchange futures market, I eliminate all risk."

Do you agree with your friend's assessment of hedging? Why or why not?

25.8 This morning you agreed to buy a two-year Treasury bond six months from today. The bond carries a 10-percent coupon rate and has a \$1,000 face. Below are listed the expected spot rates of interest for the life of the bond. These rates are semiannual rates.

Time from Today	Semiannual Rate
6 months	0.048
12 months	0.050
18 months	0.052
24 months	0.055
30 months	0.057

a. How much should you have paid for this forward contract?

b. Suppose that shortly after you purchased the forward contract, all semiannual rates increased 30 *basis points;* that is, the six-month rate increased from 0.048 to 0.051.
  i. State what you expect will happen to the value of the forward contract.
  ii. What is the value of the forward contract?

25.9 Derive the relationship between the spot price (S_0) and the futures price (F) by comparing the following two strategies:

Strategy 1: Buy the silver at S_0 today and hold it for one month.

Strategy 2: Take a long position on the silver futures contract expiring in one month. Lend money that will be equal to the futures price in one month. The lending rate for the period is the risk-free rate, r_f.

25.10 Aiko Miyazawa is a Japanese student who is planning a one-year stay in America for studying English. She expects to leave for America in eight months. Since she is worried about the unstable exchange rates, she has decided to lock in the current exchange rates. What should Aiko's hedging position be?

25.11 After reading the text's example about Ron Cooke, the mortgage banker, you decide to enter the business. You begin small; you agree to provide $300,000 to an old college roommate to finance the purchase of her home. The loan is a 20-year loan and has a 10-percent interest rate. Ten percent is the current market rate of interest. For ease of computation, assume the mortgage payments are made annually. Your former roommate needs the money four months from today. You do not have $300,000, but you intend to sell the mortgage to MAX Insurance Corp. The president of MAX is also an old friend, so you know with certainty that he will buy the mortgage. Unfortunately, he is unavailable to meet with you until three months from today.
a. What is your former roommate's mortgage payment?
b. What is the most significant risk you face in this deal?
c. How can you hedge this risk?

25.12 Refer to question 25.11. There are four-month T-bond futures available. A single contract is for $100,000 of T-bonds.
a. Suppose that between today and your meeting with the president of MAX, the market rate of interest rises to 12 percent.
i. How much is MAX's president willing to pay you for the mortgage?
ii. What will happen to the value of the T-bond futures contract?
iii. What is your net gain or loss if you wrote a futures contract?
b. Suppose that between today and your meeting with the president of MAX, the market rate of interest falls to 9 percent.
i. How much is MAX's president willing to pay you for the mortgage?
ii. What will happen to the value of the T-bond futures contract?
iii. What is your net gain or loss if you wrote a futures contract?

Duration

25.13 Available are three zero-coupon, $1,000 face-value bonds. All of these bonds are initially priced using an 11-percent interest rate. Bond *A* matures one year from today, bond *B* matures five years from today, and bond *C* matures 10 years from today.
a. What is the current price of each bond?
b. If the market rate of interest rises to 14 percent, what will be the prices of these bonds?
c. Which bond experienced the greatest percentage change in price?

25.14 Calculate the duration of a perpetuity that pays $100 at each year-end. Assume the annual discount rate of 12 percent. What if the discount rate is 10 percent?

25.15 Consider two four-year bonds. Each bond has a $1,000 face value. Bond *A*'s coupon rate is 7 percent, while bond *B*'s coupon rate is 11 percent.
a. What is the price of each bond when the market rate of interest is 10 percent?
b. What is the price of each bond when the market rate of interest is 7 percent?
c. Which bond experienced the greatest percentage change in price?
d. Explain your (*c*) result.

25.16 Calculate the duration of a three-year, $1,000 face-value bond with a 9-percent coupon rate, selling at par.

25.17 Calculate the duration of a four-year, $1,000 face-value bond with a 9-percent coupon rate, selling at par.

25.18 Calculate the duration of a four-year, $1,000 face-value bond with a 5-percent coupon rate, selling at par.

25.19 Mr. and Mrs. Chaikovski have a son who is going to enter a music college three years from today. Annual school expenses of $20,000 will occur at the beginning of each year for four years. What is the duration of Mr. and Mrs. Chaikovski's liability as parents? Assume the annual borrowing rate of 15 percent.

25.20 The following balance sheet is for Besdall Community Bank.

	Market Value	Duration
Assets		
Federal funds deposits	$ 43 million	0
Accounts-receivable loans	615 million	4 months
Short-term loans	345 million	9 months
Long-term loans	55 million	5 years
Mortgages	197 million	15 years
Liabilities and Equity		
Checking and savings deposits	$490 million	0
Certificates of deposit	370 million	18 months
Long-term financing	250 million	10 years
Equity	145 million	

a. What is the duration of Besdall's assets?
b. What is the duration of Besdall's liabilities?
c. Is Besdall Community Bank immune from interest-rate risk?

25.21 Refer to the previous problem. To what values must the durations of Besdall Community Bank change to make the bank immune from interest-rate risk if
a. Only the durations of the liabilities change?
b. Only the durations of the assets change?

25.22 Consider the following balance sheet for California Commercial Bank.

CALIFORNIA COMMERCIAL BANK
Market Value Balance Sheet

	Market Value ($ million)	Duration
Assets		
Overnight money	$ 100	0
Loans	500	1 year
Mortgages	1,200	12 years
	$1,800	
Liabilities and Equity		
Checking and savings accounts	$ 300	0
Certificates of deposit	400	1.1 year
Long-term debt	500	18.9 years
Equity	600	
	$1,800	

a. What is the duration of California's assets? What is the duration of liabilities?
b. Is the bank immunized from interest-rate risk?

Swaps

25.23 The Miller Company and the Edwards Company both need to raise money to fund facilities improvements at their manufacturing plants in New York. Miller has been in business for 40 years and has a very good credit rating. It can borrow money at either 10 percent or at the LIBOR + .03 percent floating rate. The Edwards Company has experienced some financial distress recently and does not have a strong credit history. It can borrow funds at 15 percent or 2 percent over the LIBOR rate.
a. Is there an opportunity for the Miller Company and the Edwards Company to benefit from a swap?
b. Show how you would structure a swap transaction between Miller and Edwards.