Investment, Time, and Capital Markets

15

In Chapter 14, we saw that in competitive markets, firms decide how much to purchase each month by comparing the marginal revenue product of each factor to its cost. The decisions of all firms determine the market demand for each factor, and the market price is the price that equates the quantity demanded with the quantity supplied. For factor inputs such as labor and raw materials, this picture is reasonably complete, but not so for capital. The reason is that capital is *durable*: It can last and contribute to production for years after it is purchased.

Firms sometimes rent capital in much the same way that they hire workers. For example, a firm might rent office space for a monthly fee, just as it hires a worker for a monthly wage. But more often, capital expenditures involve the purchases of factories and equipment that are expected to last for years. This introduces the element of *time*. When a firm decides whether to build a factory or purchase machines, it must compare the outlays it would have to make *now* with the additional profit that the new capital will generate *in the future*. To make this comparison, it must address the following question: *How much are future profits worth today?* This problem does not arise when hiring labor or purchasing raw materials. To make those choices, the firm need only compare its *current* expenditure on the factor—e.g., the wage or the price of steel—with the factor's *current* marginal revenue product.

In this chapter, we will learn how to calculate the current value of future flows of money. This is the basis for our study of the firm's investment decisions. Most of these decisions involve comparing an outlay today with profits that will be received in the future; we will see how firms can make this comparison and determine whether the outlay is warranted. Often, the future profits resulting from a capital investment are higher or lower than anticipated. We will see how firms can take this kind of uncertainty into account.

We will also see how individuals can make decisions involving costs and benefits occurring at different points in time. For example, we will see how a consumer choosing a new air conditioner can determine whether it makes economic sense to buy a more energy-efficient model that costs more but will result in lower electricity bills in the future. We will also discuss investments in *human capital*. Does it make economic sense, for example, to go to college or graduate school rather than take a job and start earning an income?

CHAPTER OUTLINE

LIST OF EXAMPLES

We will examine other intertemporal decisions that firms sometimes face. For example, producing a depletable resource, such as natural gas or oil, in the present means that less will be available to produce in the future. How should a producer take this into account? How long should a timber company let trees grow before harvesting them for lumber?

In §14.1, we explain that in a competitive factor market, the demand for each factor is given by its marginal revenue product—i.e., the additional revenue earned from an incremental unit of the factor.

The answers to these investment and production decisions depend in part on the *interest rate* that one pays or receives when borrowing or lending money. We will discuss the factors that determine interest rates and explain why interest rates on government bonds, corporate bonds, and savings accounts differ.

15.1 STOCKS VERSUS FLOWS

Before proceeding, we must be clear about how to measure capital and other factor inputs that firms purchase. Capital is measured as a *stock*, i.e., as a quantity of plant and equipment that the firm owns. For example, if a firm owns an electric motor factory worth \$10 million, we say that it has a *capital stock* worth \$10 million. Inputs of labor and raw materials, on the other hand, are measured as *flows*, as is the output of the firm. For example, this same firm might use 20,000 worker-hours of labor and 50,000 pounds of copper *per month* to produce 8000 electric motors *per month*. (The choice of monthly units is arbitrary; we could just as well have expressed these quantities in weekly or annual terms—for example, 240,000 worker-hours of labor per year, 600,000 pounds of copper per year, and 96,000 motors per year.)

Recall from §6.1 that a firm's production function involves flows of inputs and outputs: It turns certain amounts of labor and capital each year into an amount of output that same year.

Let's look at this producer of electric motors in more detail. Both variable cost and the rate of output are flows. Suppose the wage rate is \$15 per hour and the price of copper is 80 cents per pound. Thus the variable cost is (20,000)(\$15) + (50,000)(\$0.80) = \$340,000 *per month*. Average variable cost, on the other hand, is a cost *per unit*:

$$\frac{\$340{,}000 \text{ per month}}{8000 \text{ units per month}} = \$42.50 \text{ per unit}$$

Suppose the firm sells its motors for \$52.50 each. Then its average profit is \$52.50 − \$42.50 = \$10.00 per unit, and its total profit is \$80,000 *per month*. (Note that total profit is also a flow.) To make and sell these motors, however, the firm needs capital—namely, the factory that it built for \$10 million. *Thus the firm's \$10 million capital stock allows it to earn a flow of profit of \$80,000 per month.*

Was the \$10 million investment in this factory a sound decision? To answer this question, we must translate the \$80,000 per month profit flow into a number that we can compare with the factory's \$10 million cost. Suppose the factory is expected to last for 20 years. In that case the problem, simply put, is: What is the value today of \$80,000 per month for the next 20 years? If that value is greater than \$10 million, the investment was a good one.

A profit of \$80,000 per month for 20 years comes to (\$80,000)(20)(12) = \$19.2 million. That would make the factory seem like an excellent investment. But is \$80,000 five years—or 20 years—from now worth \$80,000 today? No, because money today can be invested—in a bank account, a bond, or other interest-bearing assets—to yield more money in the future. As a result, \$19.2 million received over the next 20 years is worth *less* than \$19.2 million today.

15.2 PRESENT DISCOUNTED VALUE

We will return to our \$10 million electric motor factory in Section 15.4, but first we must address a basic problem: *How much is \$1 paid in the future worth today?* The answer depends on the **interest rate**: the rate at which one can borrow or lend money.

• **interest rate** Rate at which one can borrow or lend money.

Suppose the annual interest rate is R. (Don't worry about which interest rate this actually is; later, we'll discuss the various types of interest rates.) Then \$1 today can be invested to yield $(1 + R)$ dollars a year from now. Therefore, $1 + R$ dollars is the *future value* of \$1 today. Now, what is the value *today*, i.e., **the present discounted value (PDV)**, of \$1 paid one year from now? The answer is easy: because $1 + R$ dollars one year from now is worth $(1 + R)/(1 + R) = \$1$ today, \$1 *a year from now is worth* $\$1/(1 + R)$ *today*. This is the amount of money that will yield \$1 after one year if invested at the rate R.

• **present discounted value (PDV)** The current value of an expected future cash flow.

What is the value today of \$1 paid *two* years from now? If \$1 were invested today at the interest rate R, it would be worth $1 + R$ dollars after one year, and $(1 + R)(1 + R) = (1 + R)^2$ dollars at the end of two years. Because $(1 + R)^2$ dollars two years from now is worth \$1 today, \$1 two years from now is worth $\$1/(1 + R)^2$ today. Similarly, \$1 paid three years from now is worth $\$1/(1 + R)^3$ today, and \$1 paid n years from now is worth $\$1/(1 + R)^n$ today.[1]

We can summarize this as follows:

$$\text{PDV of \$1 paid after 1 year} = \frac{\$1}{(1+R)}$$

$$\text{PDV of \$1 paid after 2 years} = \frac{\$1}{(1+R)^2}$$

$$\text{PDV of \$1 paid after 3 years} = \frac{\$1}{(1+R)^3}$$

$$\vdots$$

$$\text{PDV of \$1 paid after } n \text{ years} = \frac{\$1}{(1+R)^n}$$

Table 15.1 shows, for different interest rates, the present value of \$1 paid after 1, 2, 5, 10, 20, and 30 years. Note that for interest rates above 6 or 7 percent, \$1 paid 20 or 30 years from now is worth very little today. But this is not the case for low interest rates. For example, if R is 3 percent, the PDV of \$1 paid 20 years from now is about 55 cents. In other words, if 55 cents were invested now at the rate of 3 percent, it would yield about \$1 after 20 years.

Valuing Payment Streams

We can now determine the present value of a stream of payments over time. For example, consider the two payment streams in Table 15.2. Stream A comes to \$200: \$100 paid now and \$100 a year from now. Stream B comes to \$220: \$20 paid

[1] We are assuming that the annual rate of interest R is constant from year to year. Suppose the annual interest rate were expected to change, so that R_1 is the rate in year 1, R_2 is the rate in year 2, and so forth. After two years, \$1 invested today would be worth $(1 + R_1)(1 + R_2)$, so that the PDV of \$1 received two years from now is $\$1/(1 + R_1)(1 + R_2)$. Similarly, the PDV of \$1 paid n years from now is $\$1/(1 + R_1)(1 + R_2)(1 + R_3) \ldots (1 + R_n)$.

TABLE 15.1 PDV of $1 Paid in the Future

Interest Rate	1 Year	2 Years	5 Years	10 Years	20 Years	30 Years
0.01	$0.990	$0.980	$0.951	$0.905	$0.820	$0.742
0.02	0.980	0.961	0.906	0.820	0.673	0.552
0.03	0.971	0.943	0.863	0.744	0.554	0.412
0.04	0.962	0.925	0.822	0.676	0.456	0.308
0.05	0.952	0.907	0.784	0.614	0.377	0.231
0.06	0.943	0.890	0.747	0.558	0.312	0.174
0.07	0.935	0.873	0.713	0.508	0.258	0.131
0.08	0.926	0.857	0.681	0.463	0.215	0.099
0.09	0.917	0.842	0.650	0.422	0.178	0.075
0.10	0.909	0.826	0.621	0.386	0.149	0.057
0.15	0.870	0.756	0.497	0.247	0.061	0.015
0.20	0.833	0.694	0.402	0.162	0.026	0.004

TABLE 15.2 Two Payment Streams

	Today	1 Year	2 Years
Payment Stream *A*:	$100	$100	$ 0
Payment Stream *B*:	$ 20	$100	$100

now, $100 a year from now, and $100 two years from now. Which payment stream would you prefer to receive? The answer depends on the interest rate.

To calculate the present discounted value of these two streams, we compute and add the present values of each year's payment:

$$\text{PDV of Stream } A = \$100 + \frac{\$100}{(1+R)}$$

$$\text{PDV of Stream } B = \$20 + \frac{\$100}{(1+R)} + \frac{\$100}{(1+R)^2}$$

Table 15.3 shows the present values of the two streams for interest rates of 5, 10, 15, and 20 percent. As the table shows, the preferred stream depends on the interest rate. For interest rates of 10 percent or less, Stream *B* is worth more; for interest rates of 15 percent or more, Stream *A* is worth more. Why? Because even though less is paid out in Stream *A*, it is paid out sooner.

TABLE 15.3 PDV of Payment Streams

	R = .05	*R* = .10	*R* = .15	*R* = .20
PDV of Stream *A*:	$195.24	$190.91	$186.96	$183.33
PDV of Stream *B*:	205.94	193.55	182.57	172.78

EXAMPLE 15.1 The Value of Lost Earnings

In legal cases involving accidents, victims or their heirs (if the victim is killed) sue the injuring party (or an insurance company) to recover damages. In addition to compensating for pain and suffering, those damages include the future income that the injured or deceased person would have earned had the accident not occurred. To see how the present value of lost earnings can be calculated, let's examine an actual 1996 accident case. (The names and some of the data have been changed to preserve anonymity.)

Harold Jennings died in an automobile accident on January 1, 1996, at the age of 53. His family sued the driver of the other car for negligence. A major part of the damages they asked to be awarded was the present value of the earnings that Jennings would have received from his job as an airline pilot had he not been killed. The calculation of present value is typical of cases like this.

Had he worked in 1996, Jennings' salary would have been \$85,000. The normal age of retirement for an airline pilot is 60. To calculate the present value of Jennings' lost earnings, we must take several things into account. First, Jennings' salary would probably have increased over the years. Second, we cannot be sure that he would have lived to retirement had the accident not occurred; he might have died from some other cause. Therefore, the PDV of his lost earnings until retirement at the end of 2003 is

$$\begin{aligned} \text{PDV} = W_0 &+ \frac{W_0(1+g)(1-m_1)}{(1+R)} + \frac{W_0(1+g)^2(1-m_2)}{(1+R)^2} \\ &+ \cdots + \frac{W_0(1+g)^7(1-m_7)}{(1+R)^7} \end{aligned}$$

where W_0 is his salary in 1996, g is the annual percentage rate at which his salary is likely to have grown (so that $W_0(1 + g)$ would be his salary in 1997, $W_0(1 + g)^2$ his salary in 1998, etc.), and $m_1, m_2, \ldots, m_7$ are *mortality rates*, i.e., the probabilities that he would have died from some other cause by 1997, 1998, . . . , 2003.

To calculate this PDV, we need to know the mortality rates $m_1, \ldots, m_7$, the expected rate of growth of Jennings' salary g, and the interest rate R. Mortality data are available from insurance tables that provide death rates for men of similar age and race.[2] As a value for g, we can use 8 percent, the average rate of growth of wages for airline pilots over the period 1985–1995. Finally, for the interest rate we can use the rate on government bonds, which at the time was about 9 percent. (We will say more about how one chooses the correct interest rate to discount future cash flows in Sections 15.4 and 15.5.) Table 15.4 shows the details of the present value calculation.

By summing the last column, we obtain a PDV of \$650,254. If Jennings' family was successful in proving that the defendant was at fault, and if there were no other damage issues involved in the case, they could recover this amount as compensation.[3]

[2]See, for example, the *Statistical Abstract of the United States*, 2007, Table 100.

[3]Actually, this sum should be reduced by the amount of Jennings' wages which would have been spent on his own consumption and which would not therefore have benefited his wife or children.

TABLE 15.4 Calculating Lost Wages

Year	$W_0(1+g)^t$	$(1-m_t)$	$1/(1+R)^t$	$W_0(1+g)^t(1-m_t)/(1+R)^t$
1996	$ 85,000	.991	1.000	$84,235
1997	91,800	.990	.917	83,339
1998	99,144	.989	.842	82,561
1999	107,076	.988	.772	81,671
2000	115,642	.987	.708	80,810
2001	124,893	.986	.650	80,044
2002	134,884	.985	.596	79,185
2003	145,675	.984	.547	78,409

15.3 THE VALUE OF A BOND

• **bond** Contract in which a borrower agrees to pay the bondholder (the lender) a stream of money.

A **bond** is a contract in which a borrower agrees to pay the bondholder (the lender) a stream of money. For example, a corporate bond (a bond issued by a corporation) might make "coupon" payments of $100 per year for the next ten years, and then a principal payment of $1000 at the end of the ten-year period.[4] How much would you pay for such a bond? To find out how much the bond is worth, we simply compute the present value of the payment stream:

$$\text{PDV} = \frac{\$100}{(1+R)} + \frac{\$100}{(1+R)^2} + \cdots + \frac{\$100}{(1+R)^{10}} + \frac{\$1000}{(1+R)^{10}} \tag{15.1}$$

Again, the present value depends on the interest rate. Figure 15.1 shows the value of the bond—the present value of its payment stream—for interest rates up to 20 percent. Note that the higher the interest rate, the lower the value of the bond. At an interest rate of 5 percent, the bond is worth about $1386, but at an interest rate of 15 percent, its value is only $749.

Perpetuities

• **perpetuity** Bond paying out a fixed amount of money each year, forever.

A **perpetuity** is a bond that pays out a fixed amount of money each year, *forever*. How much is a perpetuity that pays $100 per year worth? The present value of the payment stream is given by the infinite summation:

$$\text{PDV} = \frac{\$100}{(1+R)} + \frac{\$100}{(1+R)^2} + \frac{\$100}{(1+R)^3} + \frac{\$100}{(1+R)^4} + \cdots$$

[4]In the United States, the coupon payments on most corporate bonds are made in semiannual installments. To keep the arithmetic simple, we will assume that they are made annually.

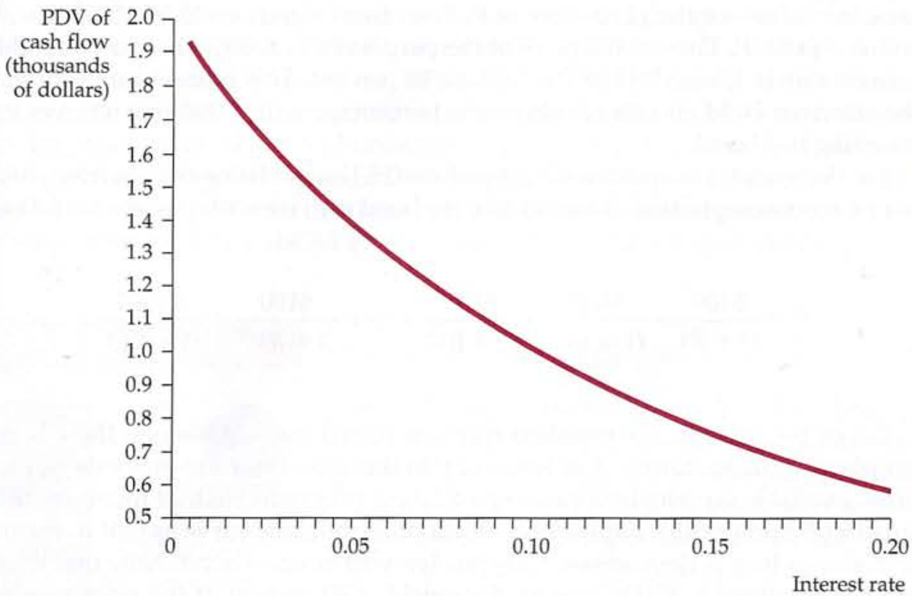


FIGURE 15.1 Present Value of the Cash Flow from a Bond

Because most of the bond's payments occur in the future, the present discounted value declines as the interest rate increases. For example, if the interest rate is 5 percent, the PDV of a 10-year bond paying $100 per year on a principal of $1000 is $1386. At an interest rate of 15 percent, the PDV is $749.

Fortunately, it isn't necessary to calculate and add up all these terms to find the value of this perpetuity; the summation can be expressed in terms of a simple formula.[5]

$$\text{PDV} = \$100/R \tag{15.2}$$

So if the interest rate is 5 percent, the perpetuity is worth $100/(.05) = $2000, but if the interest rate is 20 percent, the perpetuity is worth only $500.

The Effective Yield on a Bond

Many corporate and most government bonds are traded on the *bond market*. The value of a traded bond can be determined directly by looking at its market price—the value placed on it by buyers and sellers.[6] Thus we usually know the value of a bond, but to compare the bond with other investment opportunities, we would like to determine the interest rate consistent with that value.

Effective Yield Equations (15.1) and (15.2) show how the values of two different bonds depend on the interest rate used to discount future payments. These equations can be "turned around" to relate the interest rate to the bond's value.

[5] Let x be the PDV of $1 per year in perpetuity, so $x = 1/(1 + R) + 1/(1 + R)^2 + \ldots$. Then $x(1 + R) = 1 + 1/(1 + R) + 1/(1 + R)^2 + \ldots$, so $x(1 + R) = 1 + x$, $xR = 1$, and $x = 1/R$.

[6] The prices of actively traded corporate and U.S. government bonds are shown on financial market Web sites such as **www.yahoo.com**, **www.bloomberg.com**, and **www.schwab.com**.

This is particularly easy to do for the perpetuity. Suppose the market price—and thus the value—of the perpetuity is P. Then from equation (15.2), $P = \$100/R$, and $R = \$100/P$. Thus, if the price of the perpetuity is \$1000, we know that the interest rate is $R = \$100/\$1000 = 0.10$, or 10 percent. This interest rate is called the **effective yield**, or **rate of return**: the percentage return that one receives by investing in a bond.

• **effective yield** (or **rate of return**) Percentage return that one receives by investing in a bond.

For the ten-year coupon bond in equation (15.1), calculating the effective yield is a bit more complicated. If the price of the bond is P, we write equation (15.1) as

$$P = \frac{\$100}{(1+R)} + \frac{\$100}{(1+R)^2} + \frac{\$100}{(1+R)^3} + \cdots + \frac{\$100}{(1+R)^{10}} + \frac{\$1000}{(1+R)^{10}}$$

Given the price P, this equation must be solved for R. Although there is no simple formula to express R in terms of P in this case, there are methods (sometimes available on calculators and spreadsheet programs such as Excel) for calculating R numerically. Figure 15.2, which plots the same curve as that in Figure 15.1, shows how R depends on P for this ten-year coupon bond. Note that if the price of the bond is \$1000, the effective yield is 10 percent. If the price rises to \$1300, the effective yield drops to about 6 percent. If the price falls to \$700, the effective yield rises to over 16 percent.

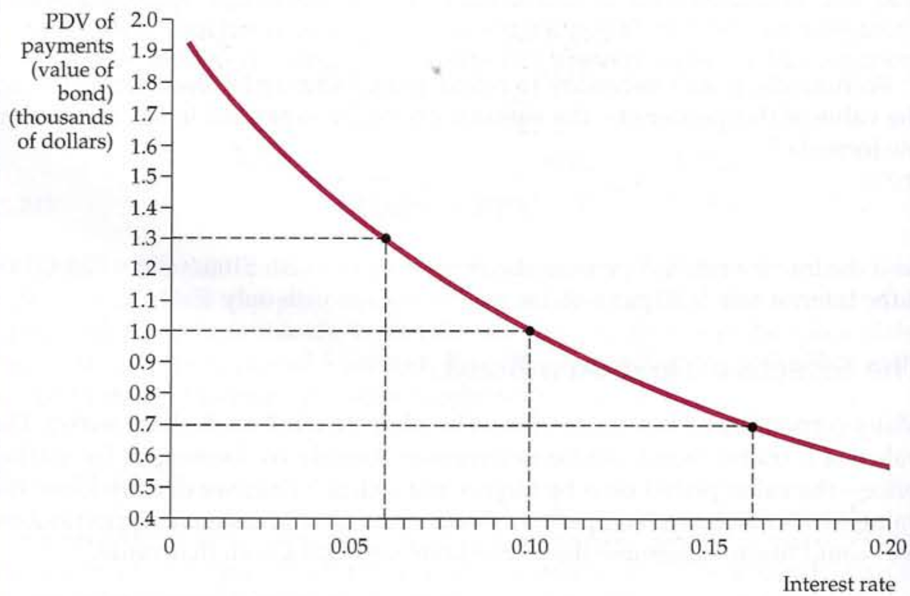


FIGURE 15.2 Effective Yield on a Bond

The effective yield is the interest rate that equates the present value of the bond's payment stream with the bond's market price. The figure shows the present value of the payment stream as a function of the interest rate. The effective yield is found by drawing a horizontal line at the level of the bond's price. For example, if the price of this bond were \$1000, its effective yield would be 10 percent. If the price were \$1300, the effective yield would be about 6 percent; if the price were \$700, it would be 16.2 percent.

Yields can differ considerably among different bonds. Corporate bonds generally yield more than government bonds, and as Example 15.2 shows, the bonds of some corporations yield much more than the bonds of others. One of the most important reasons for this is that different bonds carry different degrees of risk. The U.S. government is less likely to *default* (fail to make interest or principal payments) on its bonds than is a private corporation. And some corporations are financially stronger and therefore less likely to default than others. As we saw in Chapter 5, the more risky an investment, the greater the return that an investor demands. As a result, riskier bonds have higher yields.

EXAMPLE 15.2 The Yields on Corporate Bonds

To see how corporate bond yields are calculated—and how they can differ from one corporation to another—let's examine the yields for two coupon bonds: one issued by General Electric and the other by Ford Motor Co. Each has a *face value* of \$100, which means that when the bond matures, the holder receives a principal payment of that amount. Each bond makes a "coupon" (i.e., interest) payment every six months.[7]

We calculate the bond yields using the closing prices on August 24, 2007. The following information was downloaded from the Yahoo! Finance Web site:

	General Electric	Ford
Price:	98.77	92.00
Coupon:	5.00	8.875
Maturity Date:	Feb. 1, 2013	Jan. 15, 2022
Yield to Maturity:	5.256	9.925
Current Yield:	5.062	9.647
Rating:	AAA	CCC

What do these numbers mean? For General Electric, the price of \$98.77 was the closing price on August 24, 2007, based on a face value for the bond of \$100. The coupon of \$5.00 means that \$2.50 is paid to the owner of the bond every six months. The maturity date is the date at which the bond comes due and the owner receives the \$100 face value. The 5.256-percent yield to maturity, discussed further below, is the effective yield (i.e., rate of return) on the bond. The current yield is simply the coupon divided by the price, i.e., 5.00/98.77 = 5.062 percent. (The current yield is of limited relevance because it doesn't tell us the actual rate of return on the bond.) Finally, the GE bond is rated AAA, which is the highest rating possible for a corporate bond, indicating that the likelihood of default is very low.

[7]These bonds actually have a face value of \$1000, not \$100. The prices and coupon payments are listed as though the face value were \$100; to get the actual prices and payments, just multiply by 10 the numbers that appear on financial Web sites or in the newspaper.

How does one determine the effective yield (i.e., rate of return, or yield to maturity) on this bond? For simplicity, we'll assume that the coupon payments are made annually instead of every six months. (The error that this introduces is small.) Because the bond matures in 2013, coupon payments will be made for 2013 – 2007 = 6 years. Thus the yield is given by the following equation:

$$98.77 = \frac{5.0}{(1+R)} + \frac{5.0}{(1+R)^2} + \frac{5.0}{(1+R)^3} + \cdots + \frac{5.0}{(1+R)^6} + \frac{100}{(1+R)^6}$$

To find the effective yield, we must solve this equation for R. You can check (by substituting and checking whether the equation is satisfied) that the solution is approximately $R^* = 5.256$ percent.

The effective yield on the Ford bond is found in the same way. The bond had a price of \$92.00, made coupon payments of \$8.875 per year, and had 2022 – 2007 = 15 years to mature. Thus the equation for its yield is:

$$92.00 = \frac{8.875}{(1+R)} + \frac{8.875}{(1+R)^2} + \frac{8.875}{(1+R)^3} + \cdots + \frac{8.875}{(1+R)^{15}} + \frac{100}{(1+R)^{15}}$$

You can check that the solution to this equation is approximately $R^* = 9.925$ percent.

Why was the yield on the Ford bond so much higher than on the GE bond? Because the Ford bond was much riskier. By 2007, Ford had been experiencing billions of dollars in losses as a result of steady declines in sales of its cars and trucks, and many analysts questioned the likelihood that Ford could recover and avoid bankruptcy. Consistent with this, Ford's bond was rated CCC. Because investors knew that there was a significant possibility that Ford would default on its bond payments, they were prepared to buy the bond only if the expected return was high enough to compensate them for the risk.

15.4 THE NET PRESENT VALUE CRITERION FOR CAPITAL INVESTMENT DECISIONS

One of the most common and important decisions that firms make is to invest in new capital. Millions of dollars may be invested in a factory or machines that will last—and affect profits—for many years. The future cash flows that the investment will generate are often uncertain. And once the factory has been built, the firm usually cannot disassemble and resell it to recoup its investment—it becomes a sunk cost.

In §7.1, we explain that a sunk cost is an expenditure that has been made and cannot be recovered.

How should a firm decide whether a particular capital investment is worthwhile? It should calculate the present value of the future cash flows that it expects to receive from the investment and compare it with the cost of the investment. This method is known as the **net present value (NPV) criterion**:

• **net present value (NPV) criterion** Rule holding that one should invest if the present value of the expected future cash flow from an investment is larger than the cost of the investment.

NPV criterion: Invest if the present value of the expected future cash flows from an investment is larger than the cost of the investment.

Suppose a capital investment costs C and is expected to generate profits over the next 10 years of amounts $\pi_1, \pi_2, \ldots, \pi_{10}$. We then write the net present value as

$$\text{NPV} = -C + \frac{\pi_1}{(1+R)} + \frac{\pi_2}{(1+R)^2} + \cdots + \frac{\pi_{10}}{(1+R)^{10}} \qquad \textbf{(15.3)}$$

where R is the **discount rate** that we use to discount the future stream of profits. (R might be a market interest rate or some other rate; we will discuss how to choose it shortly.) Equation (15.3) describes the net benefit to the firm from the investment. The firm should make the investment only if that net benefit is positive—i.e., *only if NPV* > 0.

• **discount rate** Rate used to determine the value today of a dollar received in the future.

Determining the Discount Rate What discount rate should the firm use? The answer depends on the alternative ways that the firm could use its money. For example, instead of this investment, the firm might invest in another piece of capital that generates a different stream of profits. Or it might invest in a bond that yields a different return. As a result, we can think of R as the firm's **opportunity cost of capital**. Had the firm not invested in this project, it could have earned a return by investing in something else. *The correct value for* R *is therefore the return that the firm could earn on a "similar" investment.*

• **opportunity cost of capital** Rate of return that one could earn by investing in an alternate project with similar risk.

By "similar" investment, we mean one with the same *risk*. As we saw in Chapter 5, the more risky an investment, the greater the return one expects to receive from it. Therefore, the opportunity cost of investing in this project is the return that one could earn from another project or asset of similar riskiness.

We'll see how to evaluate the riskiness of an investment in the next section. For now, let's assume that this project has *no risk* (i.e., the firm is sure that the future profit flows will be π_1, π_2, etc.). In that case, the opportunity cost of the investment is the *risk-free* return—e.g., the return one could earn on a government bond. If the project is expected to last for 10 years, the firm could use the annual interest rate on a 10-year government bond to compute the NPV of the project, as in equation (15.3).[8] If the NPV is zero, the benefit from the investment would just equal the opportunity cost, so the firm should be indifferent between investing and not investing. If the NPV is greater than zero the benefit exceeds the opportunity cost, so the investment should be made.[9]

The Electric Motor Factory

In Section 15.1, we discussed a decision to invest $10 million in a factory to produce electric motors. This factory would enable the firm to use labor and copper to produce 8000 motors per month for 20 years at a cost of $42.50 each. The motors could be sold for $52.50 each, for a profit of $10 per unit, or $80,000 per month. We will assume that after 20 years, the factory will be obsolete but can be sold for scrap for $1 million. Is this a good investment? To find out, we must calculate its net present value.

We will assume for now that the $42.50 production cost and the $52.50 price at which the motors can be sold are certain, so that the firm is sure that it will receive $80,000 per month, or $960,000 per year, in profit. We also assume that

[8] This is an approximation. To be precise, the firm should use the rate on a one-year bond to discount π_1, the rate on a two-year bond to discount π_2, etc.

[9] This NPV rule is incorrect when the investment is irreversible, subject to uncertainty, and can be delayed. For a treatment of irreversible investment, see Avinash Dixit and Robert Pindyck, *Investment under Uncertainty* (Princeton, NJ: Princeton University Press, 1994).

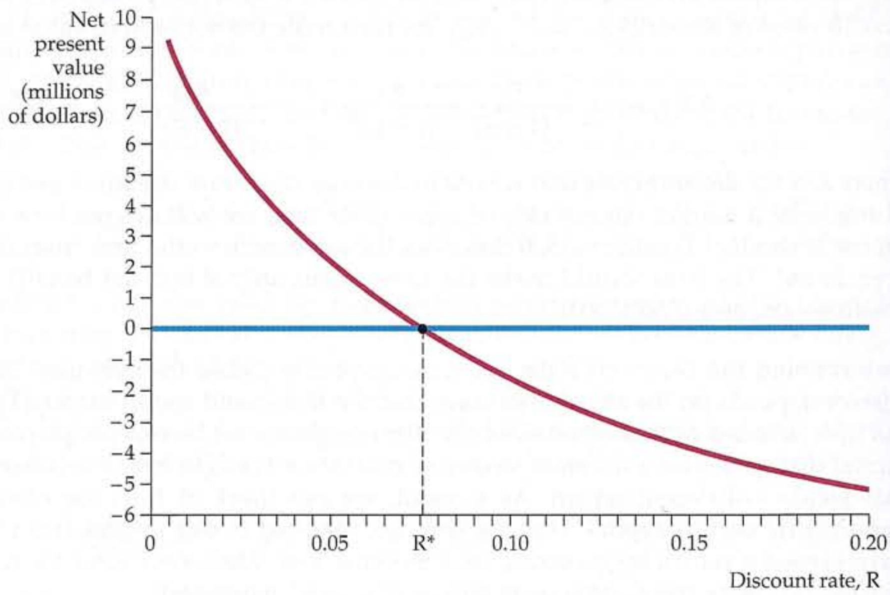


FIGURE 15.3 Net Present Value of a Factory

The NPV of a factory is the present discounted value of all the cash flows involved in building and operating it. Here it is the PDV of the flow of future profits less the current cost of construction. The NPV declines as the discount rate increases. At discount rate R^*, the NPV is zero.

the \$1 million scrap value of the factory is certain. The firm should therefore use a risk-free interest rate to discount future profits. Writing the cash flows in millions of dollars, the NPV is

$$\begin{aligned} \text{NPV} = -10 &+ \frac{.96}{(1+R)} + \frac{.96}{(1+R)^2} + \frac{.96}{(1+R)^3} \\ &+ \cdots + \frac{.96}{(1+R)^{20}} + \frac{1}{(1+R)^{20}} \end{aligned} \tag{15.4}$$

Figure 15.3 shows the NPV as a function of the discount rate R. Note that at the rate R^*, which is about 7.5 percent, the NPV is equal to zero. (The rate R^* is sometimes referred to as the *internal rate of return* on the investment.) For discount rates below 7.5 percent, the NPV is positive, so the firm should invest in the factory. For discount rates above 7.5 percent, the NPV is negative, and the firm should not invest.

Real versus Nominal Discount Rates

In the example above, we assumed that future cash flows are certain, so that the discount rate R should be a risk-free interest rate, such as the rate on U.S. government bonds. Suppose that rate happened to be 9 percent. Does that mean the NPV is negative and the firm should not invest?

To answer this question, we must distinguish between real and nominal discount rates, and between real and nominal cash flows. Let's begin with the cash flows. In Chapter 1, we discussed real versus nominal prices. We explained that whereas the real price is *net of inflation*, the nominal price includes inflation.

In our example, we assumed that the electric motors coming out of our factory could be sold for \$52.50 each over the next 20 years. We said nothing, however, about the effect of inflation. Is the \$52.50 a real price, i.e., net of inflation, or does it include inflation? As we will see, the answer to this question can be critical.

Let's assume that the \$52.50 price—and the \$42.50 production cost—are in real terms. This means that if we expect a 5-percent annual rate of inflation, the nominal price of the motors will increase from \$52.50 in the first year to (1.05)(52.50) = \$55.13 in the second year, to (1.05)(55.13) = \$57.88 in the third year, and so on. Therefore, our profit of \$960,000 per year is also in real terms.

Now let's turn to the discount rate. *If the cash flows are in real terms, the discount rate must also be in real terms.* Why? Because the discount rate is the opportunity cost of the investment. If inflation is not included in the cash flows, it should not be included in the opportunity cost either.

Opportunity cost is discussed in §7.1.

In our example, the discount rate should therefore be the real interest rate on government bonds. The nominal interest rate (9 percent) is the rate that we see in the newspapers; it includes inflation. *The real interest rate is the nominal rate minus the expected rate of inflation.*[10] If we expect inflation to be 5 percent per year on average, the real interest rate would be 9 – 5 = 4 percent. This is the discount rate that should be used to calculate the NPV of the investment in the electric motor factory. Note from Figure 15.3 that at this rate the NPV is clearly positive, so the investment should be undertaken.

When the NPV rule is used to evaluate investments, the numbers in the calculations may be in real or in nominal terms, as long as they are consistent. If cash flows are in real terms, the discount rate should also be in real terms. If a nominal discount rate is used, the effect of future inflation must also be included in the cash flows.

Negative Future Cash Flows

Factories and other production facilities can take several years to build and equip. The cost of the investment will also be spread out over several years, instead of occurring only at the outset. In addition, some investments are expected to result in *losses*, rather than profits, for the first few years. (For example, demand may be low until consumers learn about the product, or costs may start high and fall only when managers and workers have moved down the learning curve.) Negative future cash flows create no problem for the NPV rule; they are simply discounted, just like positive cash flows.

For example, suppose that our electric motor factory will take a year to build: \$5 million is spent right away, and another \$5 million is spent next year. Also, suppose the factory is expected to *lose* \$1 million in its first year of operation and \$0.5 million in its second year. Afterward, it will earn \$0.96 million a year until year 20, when it will be scrapped for \$1 million, as before. (All these cash flows are in real terms.) Now the net present value is

$$\begin{aligned} \text{NPV} = -5 - \frac{5}{(1+R)} - \frac{1}{(1+R)^2} - \frac{.5}{(1+R)^3} + \frac{.96}{(1+R)^4} + \frac{.96}{(1+R)^5} \\ + \cdots + \frac{.96}{(1+R)^{20}} + \frac{1}{(1+R)^{20}} \end{aligned} \quad \textbf{(15.5)}$$

Suppose the real interest rate is 4 percent. Should the firm build this factory? You can confirm that the NPV is negative, so this project is not a good investment.

[10] People may have different views about future inflation and may therefore have different estimates of the real interest rate.

15.5 ADJUSTMENTS FOR RISK

We have seen that a risk-free interest rate is an appropriate discount rate for future cash flows that are certain. For most projects, however, future cash flows are far from certain. At our electric motor factory, for example, we would expect uncertainty over future copper prices, over the future demand and the price of motors, and even over future wage rates. Thus the firm cannot know what its profits from the factory will be over the next 20 years. Its best estimate of profits might be $960,000 per year, but actual profits may turn out to be higher or lower. How should the firm take this uncertainty into account when calculating the net present value of the project?

• **risk premium** Amount of money that a risk-averse individual will pay to avoid taking a risk.

A common practice is to increase the discount rate by adding a **risk premium** to the risk-free rate. The idea is that the owners of the firm are risk averse, which makes future cash flows that are risky worth less than those that are certain. Increasing the discount rate takes this into account by reducing the present value of those future cash flows. But how large should the risk premium be? As we will see, the answer depends on the nature of the risk.

Diversifiable versus Nondiversifiable Risk

• **diversifiable risk** Risk that can be eliminated either by investing in many projects or by holding the stocks of many companies.

• **nondiversifiable risk** Risk that cannot be eliminated by investing in many projects or by holding the stocks of many companies.

Adding a risk premium to the discount rate must be done with care. If the firm's managers are operating in the stockholders' interests, they must distinguish between two kinds of risk—*diversifiable* and *nondiversifiable*.[11] **Diversifiable risk** can be eliminated by investing in many projects or by holding the stocks of many companies. **Nondiversifiable risk** cannot be eliminated in this way. *Only nondiversifiable risk affects the opportunity cost of capital and should enter into the risk premium.*

Diversifiable Risk To understand this, recall from Chapter 5 that diversifying can eliminate many risks. For example, I cannot know whether the result of a coin flip will be heads or tails. But I can be reasonably sure that out of a thousand coin flips, roughly half will be heads. Similarly, an insurance company that sells me life insurance cannot know how long I will live. But by selling life insurance to thousands of people, it can be reasonably sure about the percentage of those who will die each year.

Much the same is true about capital investment decisions. Although the profit flow from a single investment may be very risky, overall risk will be much less if the firm invests in dozens of projects (as most large firms do). Furthermore, even if the company invests in only one project, stockholders can easily diversify by holding the stocks of a dozen or more different companies, or by holding a mutual fund that invests in many stocks. Thus, stockholders—the owners of the firm—can eliminate diversifiable risk.

Because investors can eliminate diversifiable risk, they cannot expect to earn a return higher than the risk-free rate by bearing it: No one will pay you for bearing a risk that there is no need to bear. And indeed, assets that have only diversifiable risk tend on average to earn a return close to the risk-free rate. Now, remember that the discount rate for a project is the opportunity cost of *investing in that project rather than in some other project or asset with similar risk*

[11]Diversifiable risk is also called *nonsystematic* risk and nondiversifiable risk is called *systematic* risk. Adding a simple risk premium to the discount rate may not always be the correct way of dealing with risk. See, for example, Richard Brealey and Stewart Myers, *Principles of Corporate Finance* (New York: McGraw-Hill, 2007).

characteristics. Therefore, if the project's only risk is diversifiable, the opportunity cost is the risk-free rate. *No risk premium should be added to the discount rate.*

Nondiversifiable Risk What about nondiversifiable risk? First, let's be clear about how such risk can arise. For a life insurance company, the possibility of a major war poses nondiversifiable risk. Because a war may increase mortality rates sharply, the company cannot expect that an "average" number of its customers will die each year, no matter how many customers it has. As a result, most insurance policies, whether for life, health, or property, do not cover losses resulting from acts of war.

For capital investments, nondiversifiable risk arises because a firm's profits tend to depend on the overall economy. When economic growth is strong, corporate profits tend to be higher. (For our electric motor factory, the demand for motors is likely to be strong, so profits increase.) On the other hand, profits tend to fall in a recession. Because future economic growth is uncertain, diversification cannot eliminate all risk. Investors should (and indeed can) earn higher returns by bearing this risk.

To the extent that a project has nondiversifiable risk, the opportunity cost of investing in that project is higher than the risk-free rate. Thus a risk premium must be included in the discount rate. Let's see how the size of that risk premium can be determined.

The Capital Asset Pricing Model

The **Capital Asset Pricing Model (CAPM)** measures the risk premium for a capital investment by comparing the expected return on that investment with the expected return on the entire stock market. To understand the model, suppose, first, that you invest in the entire stock market (say, through a mutual fund). In that case, your investment would be completely diversified and you would bear no diversifiable risk. You would, however, bear nondiversifiable risk because the stock market tends to move with the overall economy. (The stock market reflects expected future profits, which depend in part on the economy.) As a result, the expected return on the stock market is higher than the risk-free rate. Denoting the expected return on the stock market by r_m and the risk-free rate by r_f, the risk premium on the market is $r_m - r_f$. This is the additional expected return you get for bearing the nondiversifiable risk associated with the stock market.

• **Capital Asset Pricing Model (CAPM)** Model in which the risk premium for a capital investment depends on the correlation of the investment's return with the return on the entire stock market.

Now consider the nondiversifiable risk associated with one asset, such as a company's stock. We can measure that risk in terms of the extent to which the return on the asset tends to be *correlated* with (i.e., move in the same direction as) the return on the stock market as a whole. For example, one company's stock might have almost no correlation with the market as a whole. On average, the price of that stock would move independently of changes in the market, so it would have little or no nondiversifiable risk. The return on that stock should therefore be about the same as the risk-free rate. Another stock, however, might be highly correlated with the market. Its price changes might even amplify changes in the market as a whole. That stock would have substantial nondiversifiable risk, perhaps more than the stock market as a whole. If so, its return on average will exceed the market return r_m.

The CAPM summarizes this relationship between expected returns and the risk premium by the following equation:

$$r_i - r_f = \beta (r_m - r_f) \qquad \textbf{(15.6)}$$

where r_i is the expected return on an asset. The equation says that the risk premium on the asset (its expected return less the risk-free rate) is proportional to the risk premium on the market. The constant of proportionality, β, is called the **asset beta**. It measures the sensitivity of the asset's return to market movements and, therefore, the asset's nondiversifiable risk. If a 1-percent rise in the market tends to result in a 2-percent rise in the asset price, the beta is 2. If a 1-percent rise in the market tends to result in a 1-percent rise in the asset price, the beta is 1. And if a 1-percent rise in the market tends to result in no change in the price of the asset, the beta is zero. As equation (15.6) shows, the larger the beta, the greater the expected return on the asset. Why? Because the asset's nondiversifiable risk is greater.

• **asset beta** A constant that measures the sensitivity of an asset's return to market movements and, therefore, the asset's nondiversifiable risk.

The Risk-Adjusted Discount Rate Given beta, we can determine the correct discount rate to use in computing an asset's net present value. That discount rate is the expected return on the asset or on another asset with the same risk. It is therefore the risk-free rate plus a risk premium to reflect nondiversifiable risk:

$$\text{Discount rate} = r_f + \beta\,(r_m - r_f) \tag{15.7}$$

Over the past 60 years, the risk premium on the stock market, $(r_m - r_f)$, has been about 8 percent on average. If the real risk-free rate were 4 percent and beta were 0.6, the correct discount rate would be $0.04 + 0.6(0.08) = 0.09$, or 9 percent.

If the asset is a stock, its beta can usually be estimated statistically.[12] When the asset is a new factory, however, determining its beta is more difficult. Many firms therefore use the company cost of capital as a (nominal) discount rate. The **company cost of capital** is a weighted average of the expected return on the company's stock (which depends on the beta of the stock) and the interest rate that it pays for debt. This approach is correct as long as the capital investment in question is typical for the company as a whole. It can be misleading, however, if the capital investment has much more or much less nondiversifiable risk than the company as a whole. In that case, it may be better to make a reasoned guess as to how much the revenues from the investment are likely to depend on the overall economy.

• **company cost of capital** Weighted average of the expected return on a company's stock and the interest rate that it pays for debt.

EXAMPLE 15.3 Capital Investment in the Disposable Diaper Industry

In Example 13.6 (page 508), we discussed the disposable diaper industry, which has been dominated by Procter & Gamble, with about a 50-percent market share, and Kimberly-Clark, with another 30–40 percent. We explained that their continuing R&D (research and development) expenditures have given these firms a cost advantage that deters entry. Now we'll examine the capital investment decision of a potential entrant.

[12] You can estimate beta by running a linear regression of the return on the stock against the excess return on the market, $r_m - r_f$. You would find, for example, that the beta for Intel Corporation is about 1.4, the beta for Eastman Kodak is about 0.8, and the beta for General Motors is about 0.5.

Suppose you are considering entering this industry. To take advantage of scale economies in production, advertising, and distribution, you would need to build three plants at a cost of \$60 million each, with the cost spread over three years. When operating at capacity, the plants would produce a total of 2.5 billion diapers per year. These would be sold at wholesale for about 16 cents per diaper, yielding revenues of about \$400 million per year. You can expect your variable production costs to be about \$290 million per year, for a net revenue of \$110 million per year.

You will, however, have other expenses. Using the experience of P&G and Kimberly-Clark as a guide, you can expect to spend about \$60 million in R&D before start-up to design an efficient manufacturing process, and another \$20 million in R&D during each year of production to maintain and improve that process. Finally, once you are operating at full capacity, you can expect to spend another \$50 million per year for a sales force, advertising, and marketing. Your net operating profit will be \$40 million per year. The plants will last for 15 years and will then be obsolete.

Is the investment a good idea? To find out, let's calculate its net present value. Table 15.5 shows the relevant numbers. We assume that production begins at 33 percent of capacity when the plant is completed in 2010, takes two years to reach full capacity, and continues through the year 2025. Given the net cash flows, the NPV is calculated as

$$\text{NPV} = -120 - \frac{93.4}{(1+R)} - \frac{56.6}{(1+R)^2} + \frac{40}{(1+R)^3} + \frac{40}{(1+R)^4} + \cdots + \frac{40}{(1+R)^{15}}$$

Table 15.5 shows the NPV for discount rates of 5, 10, and 15 percent.

Note that the NPV is positive for a discount rate of 5 percent, but it is negative for discount rates of 10 or 15 percent. What is the correct discount rate? First, we have ignored inflation, so the discount rate should be in *real* terms. Second, the cash flows are risky—we don't know how efficient our plants will be, how effective our advertising and promotion will be, or even what the future demand for

TABLE 15.5 Data for NPV Calculation (\$ millions)

	Pre-2010	2010	2011	2012	...	2025
Sales		133.3	266.7	400.0	...	400.0
LESS						
Variable cost		96.7	193.3	290.0	...	290.0
Ongoing R&D		20.0	20.0	20.0	...	20.0
Sales force, ads, and marketing		50.0	50.0	50.0	...	50.0
Operating profit		−33.4	3.4	40.0	...	40.0
LESS						
Construction cost	60.0	60.0	60.0			
Initial R&D	60.0					
NET CASH FLOW	−120.0	−93.4	−56.6	40.0	...	40.0
	Discount Rate:	0.05	0.10	0.15		
	NPV:	80.5	−16.9	−75.1		

disposable diapers will be. Some of this risk is nondiversifiable. To calculate the risk premium, we will use a beta of 1, which is typical for a producer of consumer products of this sort. Using 4 percent for the real risk-free interest rate and 8 percent for the risk premium on the stock market, our discount rate should be

$$R = 0.04 + 1(0.08) = 0.12$$

At this discount rate, the NPV is clearly negative, so the investment does not make sense. You will not enter the industry, and P&G and Kimberly-Clark can breathe a sigh of relief. Don't be surprised, however, that these firms can make money in this market while you cannot. Their experience, years of earlier R&D (they need not spend \$60 million on R&D before building new plants), and brand name recognition give them a competitive advantage that a new entrant will find hard to overcome.

15.6 INVESTMENT DECISIONS BY CONSUMERS

We have seen how firms value future cash flows and thereby decide whether to invest in long-lived capital. Consumers face similar decisions when they purchase durable goods, such as cars or major appliances. Unlike the decision to purchase food, entertainment, or clothing, the decision to buy a durable good involves comparing a flow of *future* benefits with the *current* purchase cost.

Suppose that you are deciding whether to buy a new car. If you keep the car for six or seven years, most of the benefits (and costs of operation) will occur in the future. You must therefore compare the future flow of net benefits from owning the car (the benefit of having transportation less the cost of insurance, maintenance, and gasoline) with the purchase price. Likewise, when deciding whether to buy a new air conditioner, you must compare its price with the present value of the flow of net benefits (the benefit of a cool room less the cost of electricity to operate the unit).

These problems are analogous to the problem of a firm that must compare a future flow of profits with the current cost of plant and equipment when making a capital investment decision. We can therefore analyze these problems just as we analyzed the firm's investment problem. Let's do this for a consumer's decision to buy a car.

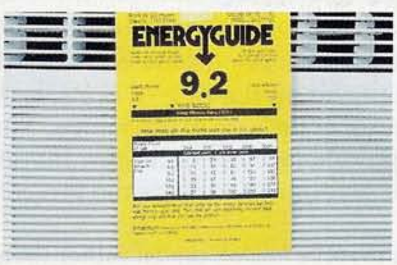
The main benefit from owning a car is the flow of transportation services it provides. The value of those services differs from consumer to consumer. Let's assume our consumer values the service at S dollars per year. Let's also assume that the total operating expense (insurance, maintenance, and gasoline) is E dollars per year, that the car costs \$20,000, and that after six years, its resale value will be \$4000. The decision to buy the car can then be framed in terms of net present value:

$$\text{NPV} = -20{,}000 + (S - E) + \frac{(S - E)}{(1 + R)} + \frac{(S - E)}{(1 + R)^2} + \cdots + \frac{(S - E)}{(1 + R)^6} + \frac{4000}{(1 + R)^6} \qquad \textbf{(15.8)}$$

What discount rate R should the consumer use? The consumer should apply the same principle that a firm does: The discount rate is the opportunity cost of money. If the consumer already has \$20,000 and does not need a loan, the correct discount rate is the return that could be earned by investing the money in another asset—say, a savings account or a government bond. On the other hand, if the consumer is in debt, the discount rate would be the borrowing rate that he or she is already paying. Because this rate is likely to be much higher than the interest rate on a bond or savings account, the NPV of the investment will be smaller.

Consumers must often make trade-offs between up-front versus future payments. An example is the decision of whether to buy or lease a new car. Suppose you can buy a new Toyota Corolla for \$15,000 and, after six years, sell it for \$6000. Alternatively, you could lease the car for \$300 per month for three years, and at the end of the three years, return the car. Which is better—buying or leasing? The answer depends on the interest rate. If the interest rate is very low, buying the car is preferable because the present value of the future lease payments is high. If the interest rate is high, leasing is preferable because the present value of the future lease payments is low.

EXAMPLE 15.4 Choosing an Air Conditioner and a New Car



Buying a new air conditioner involves making a trade-off. Some air conditioners cost less but are less efficient—they consume a lot of electricity relative to their cooling power. Others cost more but are more efficient. Should you buy an inefficient air conditioner that costs less now but will cost more to operate in the future, or an efficient one that costs more now but will cost less to operate?

Let's assume that you are comparing air conditioners of equivalent cooling power, so that they yield the same flow of benefits. We can then compare the present discounted values of their costs. Assuming an eight-year lifetime and no resale, the PDV of the cost of buying and operating air conditioner i is

$$\text{PDV} = C_i + OC_i + \frac{OC_i}{(1+R)} + \frac{OC_i}{(1+R)^2} + \cdots + \frac{OC_i}{(1+R)^8}$$

where C_i is the purchase price of air conditioner i and OC_i is its average annual operating cost.

The preferred air conditioner depends on your discount rate. If you have little free cash and must borrow, you should use a high discount rate. Because this would make the present value of the future operating costs smaller, you would probably choose a less expensive but relatively inefficient unit. If you have plenty of free cash, so that your opportunity cost of money (and thus your discount rate) is low, you would probably buy the more expensive unit.

An econometric study of household purchases of air conditioners shows that consumers tend to trade off capital costs and expected future operating costs in just this way, although the discount rates that people use are high—about

20 percent for the population as a whole.[13] (American consumers seem to behave myopically by overdiscounting future savings.) The study also shows that consumers' discount rates vary inversely with their incomes. For example, people with above-average incomes used discount rates of about 9 percent, while those in the bottom quarter of the income distribution used discount rates of 39 percent or more. We would expect this result because higher-income people are likely to have more free cash available and therefore have a lower opportunity cost of money.

Buying a new car involves a similar trade-off. One car might cost less than another but offer lower fuel efficiency and require more maintenance and repairs, so that expected future operating costs are higher. As with air conditioners, a consumer can compare two or more cars by calculating and comparing the PDV of the purchase price and expected average annual operating cost for each. An econometric study of automobile purchases found that consumers indeed trade off the purchase price and expected operating costs in this way.[14] It found the average discount rate for all consumers to be in the range of 11 to 17 percent. These discount rate estimates are somewhat lower than those for air conditioners, and probably reflect the widespread availability of auto loans.

15.7 INVESTMENTS IN HUMAN CAPITAL

So far, we have discussed how firms and consumers can decide whether to invest in *physical capital*—buildings and equipment, in the case of firms, and durable goods such as cars and major appliances, in the case of consumers. We have seen how to apply the net present value rule to these decisions: Invest when the present value of the gains from the investment exceeds the present value of the costs.

Some very important investment decisions involve *human capital* rather than physical capital. Given that you are now reading this book, you are probably making an investment in your own human capital at this very moment.[15] By studying microeconomics, perhaps as part of an undergraduate or graduate degree program, you are obtaining valuable knowledge and skills that will make you more productive in the future.

• **human capital**
Knowledge, skills, and experience that make an individual more productive and thereby able to earn a higher income over a lifetime.

Human capital is *the knowledge, skills, and experience that make an individual more productive and thereby able to earn a higher income over a lifetime*. If you go to college or graduate school, take postgraduate courses, or enroll in a specialized job training program, you are investing in human capital. Most likely, the money, time, and effort that you invest to build up your human capital will pay off in the form of more rewarding or high-paying job opportunities.

How should an individual decide whether to invest in human capital? To answer this question, we can use the same net present value rule that we have applied to investments in physical capital.

[13]See Jerry A. Hausman, "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables," *Bell Journal of Economics* 10 (Spring 1979): 33–54.

[14]See Mark K. Dreyfus and W. Kip Viscusi, "Rates of Time Preference and Consumer Valuations of Automobile Safety and Fuel Efficiency," *Journal of Law and Economics* 38 (April 1995): 79–105.

[15]On the other hand, finding this book more entertaining than a good novel, you might be reading it purely for pleasure.

Suppose, for example, that upon completing high school you are deciding whether to go to college for four years or skip college and go to work instead. To keep things as simple as possible, let's analyze this decision on a purely financial basis and ignore any pleasure (in the form of parties and football games) or pain (in the form of exams and papers) that college might entail. We will calculate the NPV of the costs and benefits of getting a college degree.

The NPV of a College Education There are two major costs associated with college. First, because you will be studying rather than working, you will incur the opportunity cost of the lost wages that you could have earned had you taken a job. For a typical high school graduate in the United States, a reasonable estimate of those lost wages would be about \$20,000 per year. The second major cost is for tuition, room and board, and related expenses (such as the cost of this book). Tuition and room and board can vary widely, depending on whether one is attending a public or private college, whether one is living at home or on campus, and whether one is receiving a scholarship. Let's use \$20,000 per year as a rough average number. (Most public universities are less expensive, but many private colleges and universities cost more.) Thus we will take the total economic cost of attending college to be \$40,000 per year for each of four years.

An important benefit of college is the ability to earn a higher salary throughout your working life. In the United States, a college graduate will on average earn about \$20,000 per year more than a high school graduate. In practice, the salary differential is largest during the first 5 to 10 years following college graduation, and then becomes smaller. For simplicity, however, we will assume that this \$20,000 salary differential persists for 20 years. In that case, the NPV (in \$1000's) of investing in a college education is

$$\text{NPV} = -40 - \frac{40}{(1+R)} - \frac{40}{(1+R)^2} - \frac{40}{(1+R)^3} + \frac{20}{(1+R)^4} + \cdots + \frac{20}{(1+R)^{23}}$$

What discount rate, R, should one use to calculate this NPV? Because we have kept the costs and benefits fixed over time, we are implicitly ignoring inflation. Thus we should use a *real* discount rate. In this case, a reasonable real discount rate would be about 5 percent. This rate would reflect the opportunity cost of money for many households—the return that could be made by investing in assets other than human capital. You can check that the NPV is then about \$66,000. With a 5-percent discount rate, investing in a college education is a good idea, at least as a purely financial matter.

In §15.4, we discuss real versus nominal discount rates, and explain that the real discount rate is the nominal rate minus the expected rate of inflation.

Although the NPV of a college education is a positive number, it is not very large. Why isn't the financial return from going to college higher? Because in the United States, entry into college has become attainable for the majority of graduating high school seniors.[16] In other words, a college education is an investment with close to free entry. As we saw in Chapter 8, in markets with free entry, we should expect to see zero economic profits, which implies that investments will earn a competitive return. Of course, a low economic return doesn't mean that you shouldn't complete your college degree—there are many benefits to a college education that go beyond increases in future earnings.

In §8.7 we explain that zero economic profit means that a firm is earning a competitive return on its investment.

[16]This is not to say that all high school graduates can go to the college of their choice. Some colleges are selective and require high grades and test scores for admission. But the large number of colleges and universities in the United States makes an undergraduate education an option for the majority of high school graduates.

EXAMPLE 15.5 Should You Go to Business School?

Many readers of this book are contemplating attending business school and earning an MBA degree or are already enrolled in an MBA program. Those of you thinking about business school (or already attending) might be wondering whether an MBA is worth the investment. Let's see if we can help you with your concern.

For most people, getting an MBA means an increase—very often a big increase—in salary. Table 15.6 shows estimates of average pre-MBA and post-MBA salaries for 25 business schools.[17] As you can see, the increases in salaries are dramatic. Bear

TABLE 15.6 Salaries Before and After Business School

University	Pre-MBA Salary	Median Base Salary after MBA
Stanford	$65,000	$165,500
Harvard	$65,000	$160,000
U. of Pennsylvania (Wharton)	$60,000	$156,000
Dartmouth (Tuck)	$50,000	$149,500
MIT (Sloan)	$55,000	$149,000
Columbia	$50,000	$142,500
Northwestern (Kellogg)	$56,000	$142,000
U. of Chicago	$55,000	$140,000
NYU (Stern)	$45,000	$140,000
UCLA (Anderson)	$55,000	$136,500
Cornell (Johnson)	$50,000	$135,000
UC—Berkeley (Haas)	$50,000	$135,000
U. of Virginia (Darden)	$50,000	$135,000
U. of Michigan	$50,000	$131,000
Yale	$45,000	$130,000
Duke (Fuqua)	$49,000	$128,500
Carnegie Mellon	$45,000	$125,000
UNC—Chapel Hill	$48,000	$125,000
Georgetown (McDonough)	$45,000	$116,000
U. of Indiana (Kelley)	$42,000	$114,000
USC (Marshall)	$45,000	$112,000
U. of Rochester (Simon)	$40,000	$110,000
Washington U. (Olin)	$42,000	$109,000
U. of Texas—Austin (McCombs)	$45,000	$107,000
Purdue (Krannert)	$35,000	$101,500

[17]The data are for students receiving their MBAs in 2005 and are from **http://www.businessschooladmission.com/mbasalaries/asp**.

in mind, however, that not all MBA programs are included in Table 15.6. Indeed, because the list includes many of the top MBA programs—and because the salaries are self-reported—they probably overstate average MBA salaries for all graduates. For the United States as a whole, a rough estimate of the average salary of students about to enter business school is around $45,000 per year and the average *increase* in salary upon obtaining the MBA degree is about $30,000 per year. For our simple analysis, we will assume that this $30,000 per year gain in salary persists for 20 years.

The typical MBA program in the United States takes two years and involves tuition and expenses of $45,000 per year. (Very few MBA students obtain scholarships.) In addition to tuition and expenses, it is important to include the opportunity cost of the foregone pre-MBA salary, i.e., another $45,000 per year. Thus, the total economic cost of getting an MBA is $90,000 per year for each of two years. The NPV of this investment is therefore

$$\text{NPV} = -90 - \frac{90}{(1+R)} + \frac{30}{(1+R)^2} + \cdots + \frac{30}{(1+R)^{21}}$$

You can check that using a real discount rate of 5 percent, the NPV comes out to about $180,000.

Why is the payoff from an MBA at schools like those listed in Table 15.6 so much higher than the payoff from a four-year undergraduate degree? Because entry into many MBA programs (and especially the programs listed in Table 15.6) is selective and difficult. (The same is true for other professional degree programs, such as law and medicine.) Because many more people apply to MBA programs than there are spaces, the return on the degree remains high.

Should you go to business school? As we have just seen, the financial part of this decision is easy: Though costly, the return on this investment is very high. Of course, there are other factors that might influence your decision. Some students, for example, find the courses they take in business school (especially economics) to be very interesting. Others find the experience to be about as much fun as having a root canal. And then there is the question of whether your undergraduate grades and test scores are sufficiently high to make this particular investment in human capital an option for you. Finally, and most importantly, you might find another career choice more rewarding, whether or not it turns out to be more profitable. We leave it to you to calculate the returns to educational investments in the arts, law, or education itself (teaching).

*15.8 INTERTEMPORAL PRODUCTION DECISIONS—DEPLETABLE RESOURCES

Production decisions often have *intertemporal* aspects—production today affects sales or costs in the future. The learning curve, which we discussed in Chapter 7, is an example of this. By producing today, the firm gains experience that lowers future costs. In this case, production today is partly an investment in future cost reduction, and the value of this investment must be taken into account when comparing costs and benefits. Another example is the production of a depletable resource. When the owner of an oil well pumps oil today, less oil is available for future production. This must be taken into account when deciding how much to produce.

Recall from §7.6 that with a learning curve, the firm's cost of production falls over time as managers and workers become more experienced and more effective at using available plant and equipment.

Production decisions in cases like these involve comparisons between costs and benefits today with costs and benefits in the future. We can make those comparisons using the concept of present discounted value. We'll look in detail at the case of a depletable resource, although the same principles apply to other intertemporal production decisions.

The Production Decision of an Individual Resource Producer

Suppose your rich uncle gives you an oil well. The well contains 1000 barrels of oil that can be produced at a constant average and marginal cost of $10 per barrel. Should you produce all the oil today, or should you save it for the future?[18]

You might think that the answer depends on the profit you can earn if you remove the oil from the ground. After all, why not remove the oil if its price is greater than the cost of extraction? However, this ignores the opportunity cost of using up the oil today so that it is not available for the future.

The correct answer, then, depends not on the current profit level but on how fast you expect the price of oil to rise. Oil in the ground is like money in the bank: You should keep it in the ground only if it earns a return at least as high as the market interest rate. If you expect the price of oil to remain constant or rise very slowly, you would be better off extracting and selling all of it now and investing the proceeds. But if you expect the price of oil to rise rapidly, you should leave it in the ground.

How fast must the price rise for you to keep the oil in the ground? The value of each barrel of oil in your well is equal to the price of oil less the $10 cost of extracting it. (This is the profit you can obtain by extracting and selling each barrel.) This value must rise at least as fast as the rate of interest for you to keep the oil. Your production decision rule is therefore: *Keep all your oil if you expect its price less its extraction cost to rise faster than the rate of interest. Extract and sell all of it if you expect price less cost to rise at less than the rate of interest.* What if you expect price less cost to rise at exactly the rate of interest? Then you would be indifferent between extracting the oil and leaving it in the ground. Letting P_t be the price of oil this year, P_{t+1} the price next year, and c the cost of extraction, we can write this production rule as follows:

If $(P_{t+1} - c) > (1 + R)(P_t - c)$, keep the oil in the ground.

If $(P_{t+1} - c) < (1 + R)(P_t - c)$, sell all the oil now.

If $(P_{t+1} - c) = (1 + R)(P_t - c)$, makes no difference.

Given our expectation about the growth rate of oil prices, we can use this rule to determine production. But how fast should we expect the market price of oil to rise?

The Behavior of Market Price

Suppose there were no OPEC cartel and the oil market consisted of many competitive producers with oil wells like our own. We could then determine how quickly oil prices are likely to rise by considering the production decisions of other producers. If other producers want to earn the highest possible return, they

[18]For most real oil wells, marginal and average cost are not constant, and it would be extremely costly to extract all the oil in a short time. We will ignore this complication.

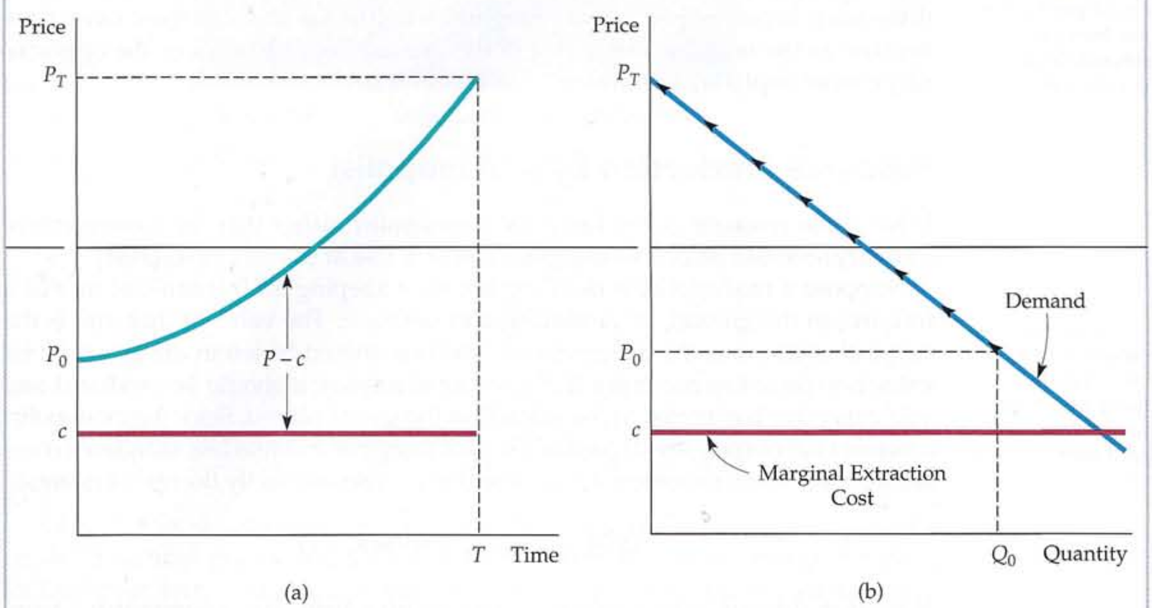


FIGURE 15.4 Price of an Exhaustible Resource

In **(a)**, the price is shown rising over time. Units of a resource in the ground must earn a return commensurate with that on other assets. Therefore, in a competitive market, price less marginal production cost will rise at the rate of interest. Part **(b)** shows the movement up the demand curve as price rises.

will follow the production rule we stated above. This means that *price less marginal cost must rise at exactly the rate of interest.*[19] To see why, suppose price less cost were to rise faster than the rate of interest. In that case, no one would sell any oil. Inevitably, this would drive up the current price. If, on the other hand, price less cost were to rise at a rate less than the rate of interest, everyone would try to sell all of their oil immediately, which would drive the current price down.

Figure 15.4 illustrates how the market price must rise. The marginal cost of extraction is c, and the price and total quantity produced are initially P_0 and Q_0. Part (a) shows the net price, $P - c$, rising at the rate of interest. Part (b) shows that as price rises, the quantity demanded falls. This continues until time T, when all the oil has been used up and the price P_T is such that demand is just zero.

User Cost

We saw in Chapter 8 that a competitive firm always produces up to the point at which price is equal to marginal cost. However, in a competitive market for an exhaustible resource, price *exceeds* marginal cost (and the difference between price and marginal cost rises over time). Does this conflict with what we learned in Chapter 8?

No, once we recognize that the *total* marginal cost of producing an exhaustible resource is greater than the marginal cost of extracting it from the ground. There is an additional opportunity cost because producing and selling a unit today makes it unavailable for production and sale in the future. We call

[19]This result is called the *Hotelling rule* because it was first demonstrated by Harold Hotelling in "The Economics of Exhaustible Resources," *Journal of Political Economy* 39 (April 1931): 137–75.

• user cost of production Opportunity cost of producing and selling a unit today and so making it unavailable for production and sale in the future.

this opportunity cost the **user cost of production**. In Figure 15.4, user cost is the difference between price and marginal production cost. It rises over time because as the resource remaining in the ground becomes scarcer, the opportunity cost of depleting another unit becomes higher.

Resource Production by a Monopolist

What if the resource is produced by a *monopolist* rather than by a competitive industry? Should price less marginal cost still rise at the rate of interest?

In §10.1, we explain that a monopolist maximizes its profit by choosing an output at which marginal revenue is equal to marginal cost.

Suppose a monopolist is deciding between keeping an incremental unit of a resource in the ground, or producing and selling it. The value of that unit is the *marginal revenue* less the marginal cost. The unit should be left in the ground if its value is expected to rise faster than the rate of interest; it should be produced and sold if its value is expected to rise at *less* than the rate of interest. Since the monopolist controls total output, it will produce so that marginal revenue less marginal cost—i.e., the value of an incremental unit of resource—rises at exactly the rate of interest:

$$(\mathrm{MR}_{t+1} - c) = (1 + R)(\mathrm{MR}_t - c)$$

Note that this rule also holds for a competitive firm. For a competitive firm, however, marginal revenue equals the market price p.

For a monopolist facing a downward-sloping demand curve, price is greater than marginal revenue. Therefore, if marginal revenue less marginal cost rises at the rate of interest, *price* less marginal cost will rise at less than the rate of interest. We thus have the interesting result that a monopolist is *more conservationist* than a competitive industry. In exercising monopoly power, the monopolist starts out charging a higher price and depletes the resource more slowly.

EXAMPLE 15.6 How Depletable Are Depletable Resources?

Resources such as oil, natural gas, coal, uranium, copper, iron, lead, zinc, nickel, and helium are all depletable: Because there is a finite amount of each in the earth's crust, the production and consumption of each will ultimately cease. Nonetheless, some resources are more depletable than others.

For oil, natural gas, and helium, known and potentially discoverable in-ground reserves are equal to only 50 to 100 years of current consumption. For these resources, the user cost of production can be a significant component of the market price. Other resources, such as coal and iron, have a proven and potential reserve base equal to several hundred or even thousands of years of current consumption. For these resources, the user cost is very small.

The user cost for a resource can be estimated from geological information about existing and potentially discoverable reserves, and from knowledge of the demand curve and the rate at which that curve is likely to shift out over time in response to economic growth. If the market is competitive, user cost can be determined from the economic rent earned by the owners of resource-bearing lands.

TABLE 15.7 User Cost as a Fraction of Competitive Price

Resource	User Cost/Competitive Price
Crude oil	.4 to .5
Natural gas	.4 to .5
Uranium	.1 to .2
Copper	.2 to .3
Bauxite	.05 to .2
Nickel	.1 to .3
Iron ore	.1 to .2
Gold	.05 to .1

Table 15.7 shows estimates of user cost as a fraction of the competitive price for crude oil, natural gas, uranium, copper, bauxite, nickel, iron ore, and gold.[20] Note that only for crude oil and natural gas is user cost a substantial component of price. For the other resources, it is small and in some cases almost negligible. Moreover, although most of these resources have experienced sharp price fluctuations, user cost had almost nothing to do with those fluctuations. For example, oil prices changed because of OPEC and political turmoil in the Persian Gulf, natural gas prices because of changes in energy demand, uranium and bauxite prices because of cartelization during the 1970s, and copper prices because of strikes and changes in demand.

Resource depletion, then, has not been very important as a determinant of resource prices over the past few decades. Much more important have been market structure and changes in market demand. But the role of depletion should not be ignored. Over the long term, it will be the ultimate determinant of resource prices.

15.9 HOW ARE INTEREST RATES DETERMINED?

We have seen how market interest rates are used to help make capital investment and intertemporal production decisions. But what determines interest rate levels? Why do they fluctuate over time? To answer these questions, remember that an interest rate is the price that borrowers pay lenders to use their funds. Like any market price, interest rates are determined by supply and demand—in this case, the supply and demand for loanable funds.

The *supply of loanable funds* comes from households that wish to save part of their incomes in order to consume more in the future (or make bequests to their heirs).

[20]These numbers are based on Michael J. Mueller, "Scarcity and Ricardian Rents for Crude Oil," *Economic Inquiry* 23 (1985): 703–24; Kenneth R. Stollery, "Mineral Depletion with Cost as the Extraction Limit: A Model Applied to the Behavior of Prices in the Nickel Industry," *Journal of Environmental Economics and Management* 10 (1983): 151–65; Robert S. Pindyck, "On Monopoly Power in Extractive Resource Markets," *Journal of Environmental Economics and Management* 14 (1987): 128–42; Martin L. Weitzman, "Pricing the Limits to Growth from Mineral Depletion," *Quarterly Journal of Economics* 114 (May 1999): 691–706; and Gregory M. Ellis and Robert Halvorsen, "Estimation of Market Power in a Nonrenewable Resource Industry," *Journal of Political Economy* 110 (2002): 883–99.

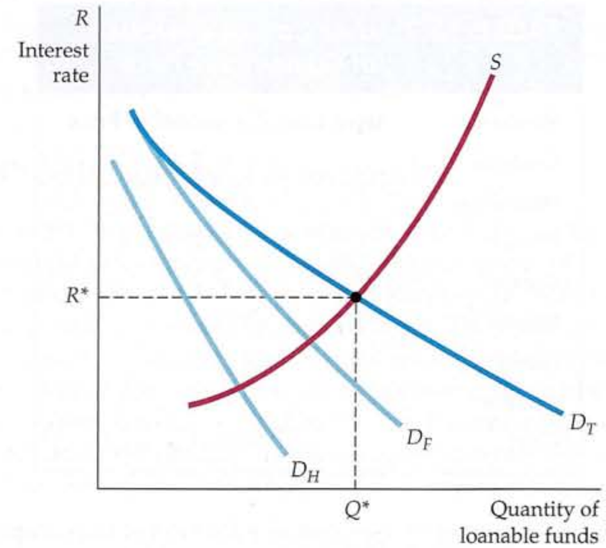


FIGURE 15.5 Supply and Demand for Loanable Funds

Market interest rates are determined by the demand and supply of loanable funds. Households supply funds in order to consume more in the future; the higher the interest rate, the more they supply. Households and firms both demand funds, but the higher the interest rate, the less they demand. Shifts in demand or supply cause changes in interest rates.

For example, some households have high incomes now but expect to earn less after retirement. Saving lets them spread their consumption more evenly over time. In addition, because they receive interest on the money they lend, they can consume more in the future in return for consuming less now. As a result, the higher the interest rate, the greater the incentive to save. The supply of loanable funds is therefore an upward-sloping curve, labeled S in Figure 15.5.

The *demand for loanable funds* has two components. First, some households want to consume more than their current incomes, either because their incomes are low now but are expected to grow, or because they want to make a large purchase (e.g., a house) that must be paid for out of future income. These households are willing to pay interest in return for not having to wait to consume. However, the higher the interest rate, the greater the cost of consuming rather than waiting, so the less willing these households will be to borrow. The household demand for loanable funds is therefore a declining function of the interest rate. In Figure 15.5, it is the curve labeled D_H.

The second source of demand for loanable funds is firms that want to make capital investments. Remember that firms will invest in projects with NPVs that are positive because a positive NPV means that the expected return on the project exceeds the opportunity cost of funds. That opportunity cost—the discount rate used to calculate the NPV—is the interest rate, perhaps adjusted for risk. Often firms borrow to invest because the flow of profits from an investment comes in the future while the cost of an investment must usually be paid now. The desire of firms to invest is thus an important source of demand for loanable funds.

As we saw earlier, however, the higher the interest rate, the lower the NPV of a project. If interest rates rise, some investment projects that had positive NPVs will now have negative NPVs and will therefore be cancelled. Overall, because firms' willingness to invest falls when interest rates rise, their demand for loanable funds also falls. The demand for loanable funds by firms is thus a downward-sloping curve; in Figure 15.5, it is labeled D_F.

The total demand for loanable funds is the sum of household demand and firm demand; in Figure 15.5, it is the curve D_T. This total demand curve, together with the supply curve, determines the equilibrium interest rate. In Figure 15.5, that rate is R^*.

Figure 15.5 can also help us understand why interest rates change. Suppose the economy goes into a recession. Firms will expect lower sales and lower future profits from new capital investments. The NPVs of projects will fall, and firms' willingness to invest will decline, as will their demand for loanable funds. D_F, and therefore D_T, will shift to the left, and the equilibrium interest rate will fall. Or suppose the federal government spends much more money than it collects through taxes—i.e., that it runs a large deficit. It will have to borrow to finance the deficit, shifting the total demand for loanable funds D_T to the right, so that R increases. The monetary policies of the Federal Reserve are another important determinant of interest rates. The Federal Reserve can create money, shifting the supply of loanable funds to the right and reducing R.

A Variety of Interest Rates

Figure 15.5 aggregates individual demands and supplies as though there were a single market interest rate. In fact, households, firms, and the government lend and borrow under a variety of terms and conditions. As a result, there is a wide range of "market" interest rates. Here we briefly describe some of the more important rates that are quoted in the newspapers and sometimes used for capital investment decisions.

- **Treasury Bill Rate** A Treasury bill is a short-term (one year or less) bond issued by the U.S. government. It is a pure *discount bond*—i.e., it makes no coupon payments but instead is sold at a price less than its redemption value at maturity. For example, a three-month Treasury bill might be sold for \$98. In three months, it can be redeemed for \$100; it thus has an effective three-month yield of about 2 percent and an effective annual yield of about 8 percent.[21] The Treasury bill rate can be viewed as a short-term, risk-free rate.
- **Treasury Bond Rate** A Treasury bond is a longer-term bond issued by the U.S. government for more than one year and typically for 10 to 30 years. Rates vary, depending on the maturity of the bond.
- **Discount Rate** Commercial banks sometimes borrow for short periods from the Federal Reserve. These loans are called *discounts*, and the rate that the Federal Reserve charges on them is the discount rate.
- **Federal Funds Rate** This is the interest rate that banks charge one another for overnight loans of federal funds. Federal funds consist of currency in circulation plus deposits held at Federal Reserve Banks. Banks keep funds at Federal Reserve Banks in order to meet reserve requirements. Banks with excess reserves may lend these funds to banks with reserve deficiencies at the federal funds rate. The federal funds rate is a key instrument of monetary policy used by the Federal Reserve.
- **Commercial Paper Rate** Commercial paper refers to short-term (six months or less) discount bonds issued by high-quality corporate borrowers. Because

[21] To be exact, the three-month yield is $(100/98) - 1 = 0.0204$, and the annual yield is $(100/98)^4 - 1 = 0.0842$, or 8.42 percent.

commercial paper is only slightly riskier than Treasury bills, the commercial paper rate is usually less than 1 percent higher than the Treasury bill rate.

- **Prime Rate** This is the rate (sometimes called the *reference rate*) that large banks post as a reference point for short-term loans to their biggest corporate borrowers. As we saw in Example 12.4 (page 467), this rate does not fluctuate from day to day as other rates do.
- **Corporate Bond Rate** Newspapers and government publications report the average annual yields on long-term (typically 20-year) corporate bonds in different risk categories (e.g., high-grade, medium-grade, etc.). These average yields indicate how much corporations are paying for long-term debt. However, as we saw in Example 15.2, the yields on corporate bonds can vary considerably, depending on the financial strength of the corporation and the time to maturity for the bond.

SUMMARY

1. A firm's holding of capital is measured as a stock, but inputs of labor and raw materials are flows. Its stock of capital enables a firm to earn a flow of profits over time.
2. When a firm makes a capital investment, it spends money now in order to earn profits in the future. To decide whether the investment is worthwhile, the firm must determine the present value of future profits by discounting them.
3. The present discounted value (PDV) of \$1 paid one year from now is $\$1/(1 + R)$, where R is the interest rate. The PDV of \$1 paid n years from now is $\$1/(1 + R)^n$.
4. A bond is a contract in which a lender agrees to pay the bondholder a stream of money. The value of the bond is the PDV of that stream. The effective yield on a bond is the interest rate that equates that value with the bond's market price. Bond yields differ because of differences in riskiness and time to maturity.
5. Firms can decide whether to undertake a capital investment by applying the net present value (NPV) criterion: Invest if the present value of the expected future cash flows is larger than the cost of the investment.
6. The discount rate that a firm uses to calculate the NPV for an investment should be the opportunity cost of capital—i.e., the return the firm could earn on a similar investment.
7. When calculating NPVs, if cash flows are in nominal terms (i.e., include inflation), the discount rate should also be nominal; if cash flows are in real terms (i.e., are net of inflation), a real discount rate should be used.
8. An adjustment for risk can be made by adding a risk premium to the discount rate. However, the risk premium should reflect only nondiversifiable risk. Using the Capital Asset Pricing Model (CAPM), the risk premium is the "asset beta" for the project multiplied by the risk premium on the stock market as a whole. The "asset beta" measures the sensitivity of the project's return to movements in the market.
9. Consumers are faced with investment decisions that require the same kind of analysis as those of firms. When deciding whether to buy a durable good like a car or a major appliance, the consumer must consider the present value of future operating costs.
10. Investments in human capital—the knowledge, skills, and experience that make an individual more productive and thereby able to earn a higher income in the future—can be evaluated in much the same way as other investments. Investing in further education, for example, makes economic sense if the present value of the expected future increases in income exceeds the present value of the costs.
11. An exhaustible resource in the ground is like money in the bank and must earn a comparable return. Therefore, if the market is competitive, price less marginal extraction cost will grow at the rate of interest. The difference between price and marginal cost is called *user cost*—the opportunity cost of depleting a unit of the resource.
12. Market interest rates are determined by the demand and supply of loanable funds. Households supply funds so that they can consume more in the future. Households, firms, and the government demand funds. Changes in demand or supply cause changes in interest rates.

QUESTIONS FOR REVIEW

1. A firm uses cloth and labor to produce shirts in a factory that it bought for \$10 million. Which of its factor inputs are measured as flows and which as stocks? How would your answer change if the firm had leased a factory instead of buying one? Is its output measured as a flow or a stock? What about its profit?

2. How do investors calculate the net present value of a bond? If the interest rate is 5 percent, what is the present value of a perpetuity that pays $1000 per year forever?
3. What is the *effective yield* on a bond? How does one calculate it? Why do some corporate bonds have higher effective yields than others?
4. What is the net present value (NPV) criterion for investment decisions? How does one calculate the NPV of an investment project? If all the cash flows for a project are certain, what discount rate should be used to calculate NPV?
5. You are retiring from your job and are given two options: You can accept a lump sum payment from the company, or you can accept a smaller annual payment that will continue for as long as you live. How would you decide which option is best? What information do you need?
6. You have noticed that bond prices have been rising over the past few months. All else equal, what does this suggest has been happening to interest rates? Explain.
7. What is the difference between a real discount rate and a nominal discount rate? When should a real discount rate be used in an NPV calculation and when should a nominal rate be used?
8. How is risk premium used to account for risk in NPV calculations? What is the difference between diversifiable and nondiversifiable risk? Why should only nondiversifiable risk enter into the risk premium?
9. What is meant by the "market return" in the Capital Asset Pricing Model (CAPM)? Why is the market return greater than the risk-free interest rate? What does an asset's "beta" measure in the CAPM? Why should high-beta assets have a higher expected return than low-beta assets?
10. Suppose you are deciding whether to invest $100 million in a steel mill. You know the expected cash flows for the project, but they are risky—steel prices could rise or fall in the future. How would the CAPM help you select a discount rate for an NPV calculation?
11. How does a consumer trade off current and future costs when selecting an air conditioner or other major appliance? How could this selection be aided by an NPV calculation?
12. What is meant by the "user cost" of producing an exhaustible resource? Why does price minus extraction cost rise at the rate of interest in a competitive market for an exhaustible resource?
13. What determines the supply of loanable funds? The demand for loanable funds? What might cause the supply or demand for loanable funds to shift? How would such a shift affect interest rates?

EXERCISES

1. Suppose the interest rate is 10 percent. If $100 is invested at this rate today, how much will it be worth after one year? After two years? After five years? What is the value today of $100 paid one year from now? Paid two years from now? Paid five years from now?
2. You are offered the choice of two payment streams: (a) $150 paid one year from now and $150 paid two years from now; (b) $130 paid one year from now and $160 paid two years from now. Which payment stream would you prefer if the interest rate is 5 percent? If it is 15 percent?
3. Suppose the interest rate is 10 percent. What is the value of a coupon bond that pays $80 per year for each of the next five years and then makes a principal repayment of $1000 in the sixth year? Repeat for an interest rate of 15 percent.
4. A bond has two years to mature. It makes a coupon payment of $100 after one year and both a coupon payment of $100 and a principal repayment of $1000 after two years. The bond is selling for $966. What is its effective yield?
5. Equation (15.5) (page 563) shows the net present value of an investment in an electric motor factory. Half of the $10 million cost is paid initially and the other half after a year. The factory is expected to lose money during its first two years of operation. If the discount rate is 4 percent, what is the NPV? Is the investment worthwhile?
6. The market interest rate is 5 percent and is expected to stay at that level. Consumers can borrow and lend all they want at this rate. Explain your choice in each of the following situations:
   a. Would you prefer a $500 gift today or a $540 gift next year?
   b. Would you prefer a $100 gift now or a $500 loan without interest for four years?
   c. Would you prefer a $350 rebate on an $8000 car or one year of financing for the full price of the car at 0 percent interest?
   d. You have just won a million-dollar lottery and will receive $50,000 a year for the next 20 years. How much is this worth to you today?
   e. You win the "honest million" jackpot. You can have $1 million today or $60,000 per year for eternity (a right that can be passed on to your heirs). Which do you prefer?
   f. In the past, adult children had to pay taxes on gifts of over $10,000 from their parents, but parents could make interest-free loans to their children. Why did some people call this policy unfair? To whom were the rules unfair?
7. Ralph is trying to decide whether to go to graduate school. If he spends two years in graduate school, paying $15,000 tuition each year, he will get a job that will pay $60,000 per year for the rest of his working life. If

he does not go to school, he will go into the workforce immediately. He will then make $30,000 per year for the next three years, $45,000 for the following three years, and $60,000 per year every year after that. If the interest rate is 10 percent, is graduate school a good financial investment?

8. Suppose your uncle gave you an oil well like the one described in Section 15.8. (Marginal production cost is constant at $10.) The price of oil is currently $20 but is controlled by a cartel that accounts for a large fraction of total production. Should you produce and sell all your oil now or wait to produce? Explain your answer.

9. You are planning to invest in fine wine. Each case costs $100, and you know from experience that the value of a case of wine held for t years is $100t^{1/2}$. One hundred cases of wine are available for sale, and the interest rate is 10 percent.
   a. How many cases should you buy, how long should you wait to sell them, and how much money will you receive at the time of their sale?
   b. Suppose that at the time of purchase, someone offers you $130 per case immediately. Should you take the offer?
   c. How would your answers change if the interest rate were only 5 percent?

10. Reexamine the capital investment decision in the disposable diaper industry (Example 15.3) from the point of view of an incumbent firm. If P&G or Kimberly-Clark were to expand capacity by building three new plants, they would not need to spend $60 million on R&D before start-up. How does this advantage affect the NPV calculations in Table 15.5 (page 567)? Is the investment profitable at a discount rate of 12 percent?

11. Suppose you can buy a new Toyota Corolla for $20,000 and sell it for $12,000 after six years. Alternatively, you can lease the car for $300 per month for three years and return it at the end of the three years. For simplification, assume that lease payments are made yearly instead of monthly—i.e., that they are $3600 per year for each of three years.
   a. If the interest rate, r, is 4 percent, is it better to lease or buy the car?
   b. Which is better if the interest rate is 12 percent?
   c. At what interest rate would you be indifferent between buying and leasing the car?

12. A consumer faces the following decision: She can buy a computer for $1000 and $10 per month for Internet access for three years, or she can receive a $400 rebate on the computer (so that its cost is $600) but agree to pay $25 per month for three years for Internet access. For simplification, assume that the consumer pays the access fees yearly (i.e., $10 per month = $120 per year).
   a. What should the consumer do if the interest rate is 3 percent?
   b. What if the interest rate is 17 percent?
   c. At what interest rate will the consumer be indifferent between the two options?