you can earn if you sell the oil if its price is the opportunity the future profit level, but on id is like money in it earns a return at the price of oil re-extracting and sell-in the price of oil (d) ground? The value 1, less the $10 cost of selling each interest for you to keep all your oil if you stop the rate of interest. The rate of interest? 1d leaving it in the rice next year, and s follows:...ground.

so, we can use this at the market price cost consisted of many d then determine extraction decisions the possible re-This means that To see why, suppose. Then no one price of oil up. If, than the rate of in-

![Figure 15.4](attachment://image.png)

**Figure 15.4: Price of an Exhaustible Resource.** In (a), the price is shown rising over time. Due to a resource of the ground must earn a return commensurate with that of other assets. Therefore, in a competitive market, price less marginal production cost will equal the rate of interest. panel (b) shows movement in the demand curve as price rises.

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 $Q_0$. Figure 15.4a shows the net price, $P - c$, rising at the rate of interest. Figure 15.4b 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 where 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
Resource Production by a Monopolist

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

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:

\[(MR_{t+1} - c) = (1 + R)(MR_t - c)\]

Note that this rule also holds for a competitive firm, but for a competitive firm, marginal revenue equals the market price \(p\).

For a monopolist facing a downward-sloping demand curve, price is greater than marginal revenue. Hence, 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 15.5: How Depletable Are Depletable Resources?

Resources like oil, natural gas, coal, uranium, copper, iron, lead, zinc, nickel, and helium are all depletable—there is a finite amount of each in the earth’s crust, so that ultimately the production and consumption of each will 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 depletion can be a significant component of the market price. Other resources, such as coal and iron, have a proved 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. Or if the market is competitive, user cost can be determined from the economic rent earned by the owners of resource-bearing lands.

Table 15.6 shows estimates of user cost as a fraction of the competitive price for crude oil, natural gas, uranium, copper, bauxite, and nickel. 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 government price controls, uranium and bauxite because of cartelization during the 1970s, and copper because of major 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.

<table>
<thead>
<tr>
<th>Resource</th>
<th>User Cost/Competitive Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Oil</td>
<td>4-5%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>4-5%</td>
</tr>
<tr>
<td>Uranium</td>
<td>10%</td>
</tr>
<tr>
<td>Copper</td>
<td>15%</td>
</tr>
<tr>
<td>Bauxite</td>
<td>15%</td>
</tr>
<tr>
<td>Nickel</td>
<td>10%</td>
</tr>
</tbody>
</table>

15.8 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 how high interest rates will be and why 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). For example, some households have high incomes now but expect to earn less in the future after retirement. Saving lets them spread their consumption more evenly over time. Also, 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.

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**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 to consume more in the future; the higher the interest rate, the more they supply. Households and firms both demand funds, but they demand less the higher the interest rate is. Shifts in demand or supply cause changes in interest rates.
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 has to 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 NPV's 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. Firms' desires to invest are 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 the household demand and the firm demand; in Figure 15.5 it is the curve \( D_T \). This total demand curve together with the supply curve determine 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 then 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 takes through taxes, i.e., runs large deficits, as it has done since the 1980s. It will have to borrow to finance these deficits, 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 interest rates that are quoted in the newspapers, and some-
times used for capital investment decisions.

**Treasury Bill Rate**  A Treasury bill is a short-term (one year or less) bond is-
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 ma-
turity. 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.\(^\text{19}\) 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 (more than one
year, and typically 10 to 30 years) issued by the U.S. government. 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.

**Commercial Paper Rate**  Commercial paper refers to short-term (six months
or less) discount bonds issued by high-quality corporate borrowers. Because
commercial paper is only slightly riskier than a Treasury bill, 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, 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 dif-
f erent risk categories (e.g., high-grade bonds, medium-grade bonds, 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.

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**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.

\(^{19}\) To be exact, the three-month yield is \(\frac{1000 - 98}{1000} = 0.0204\), and the annual yield is \(\left(\frac{1000}{98}\right)^4 - 1 = 0.0842\), or 8.42 percent.
2. When a firm makes a capital investment, it spends money now, so that it can 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 from an investment 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, but 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 "beta" for the project times the risk premium on the stock market as a whole. The "beta" measures the sensitivity of the project's return to movements in the market.

9. Consumers are also 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. 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—it is the opportunity cost of depleting a unit of the resource.

11. Market interest rates are determined by the demand and supply of loanable funds. Households supply funds so 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? Its profit?

2. 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?
3. You are offered the choice of two payment streams: (a) $100 paid one year from now and $100 paid two years from now; (b) $80 paid one year from now and $130 paid two years from now. Which payment stream would you prefer if the interest rate is 5 percent? If it is 15 percent?

4. How does one calculate the 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?

5. What is the effective yield on a bond? How does one calculate it? Why do some corporate bonds have effective yields that are higher than others?

6. 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 the project are certain, what discount rate should be used to calculate the NPV?

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 a 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 exhaustible resource market?

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, and how would that affect interest rates?

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**Exercises**

1. 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.

2. 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?

3. Equation (15.5) shows the net present value of an investment in an electric motor factory, where half of the $10 million cost is paid initially and the other half after a year, and where 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?

4. The market interest rate is 10 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 $250 rebate on an $8000 car or one year of financing for the full price of the car at 5 percent interest?
d. Suppose you win the "million dollar lottery." You 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 $50,000 per year for eternity (this right can be passed on to your heirs). Which do you prefer?

f. Until recently, an adult child had to pay taxes on gifts of over $10,000 from her parents, but parents could loan money to their children interest-free. Why did some people call this unfair? To whom were the rules unfair?

5. Ralph is trying to decide whether to go to graduate school. If he spends two years in graduate school, paying $10,000 tuition each year, he will get a job that will pay $50,000 per year for the rest of his working life. If he does not go to school, he will go into the work force immediately. He will then make $20,000 per year for the next three years, $30,000 for the following three years, and $50,000 per year every year after that. If the interest rate is 10 percent, is graduate school a good financial investment?

6. Suppose your uncle gave you an oil well like the one described in Section 15.7. (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.

7. 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 \((100)\times(1.1)^t\). 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?

8. 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 affect the NPV calculations in Table 15.5? Is the investment profitable at a discount rate of 12 percent?