Thus the price of wheat (in nominal terms) rose considerably since 1981. In fact, nearly all of this increase occurred during 2005 to 2007. (In 2002, for example, the price of wheat was only $2.78 per bushel.) The causes? Dry weather in 2005, even dryer weather in 2006, and heavy rains in 2007 combined with increased export demand. You can check to see that, at the 2007 price and quantity, the price elasticity of demand was −0.35 and the price elasticity of supply 0.32. Given these low elasticities, it is not surprising that the price of wheat rose so sharply.[9]

International demand for U. S. wheat fluctuates with the weather and political conditions in other major wheat producing countries, such as China, India and Russia. Between 2008 and 2010, U.S. wheat exports fell by 30% in the face of robust international production, so the price of wheat reached a low of $4.87 in 2010, down from $6.48 two years earlier. Inclement weather led to shortfalls in 2011, however, and U.S. exports shot up by 33%, driving the price up to $5.70 in 2011.

We found that the market-clearing price of wheat was $3.46 in 1981, but in fact the price was greater than this. Why? Because the U.S. government bought wheat through its price support program. In addition, farmers have been receiving direct subsidies for the wheat they produce. This aid to farmers (at the expense of taxpayers) has increased in magnitude. In 2002—and again in 2008—Congress passed legislation continuing (and in some cases expanding) subsidies to farmers. The Food, Conservation, and Energy Act of 2008 authorized farm aid through 2012, at a projected cost of $284 billion over five years. Recent U.S. budget crises, however, have given support to those in Congress who feel these subsidies should end.[10]

Agricultural policies that support farmers exist in the United States, Europe, Japan, and many other countries. We discuss how these policies work, and evaluate the costs and benefits for consumers, farmers, and the government budget in Chapter 9.

2.5 Short-Run versus Long-Run Elasticities

When analyzing demand and supply, we must distinguish between the short run and the long run. In other words, if we ask how much demand or supply changes in response to a change in price, we must be clear about *how much time is allowed to pass before we measure the changes in the quantity demanded or supplied*. If we allow only a short time to pass—say, one year or less—then we are dealing with the *short run*. When we refer to the *long run* we mean that enough time is allowed for consumers or producers to *adjust fully* to the price change. In general, short-run demand and supply curves look very different from their long-run counterparts.

[9] These are short-run elasticity estimates from Economics Research Service (ERS) of the U.S. Department of Agriculture (USDA). For more information, consult the following publications: William Lin, Paul C. Westcott, Robert Skinner, Scott Sanford, and Daniel G. De La Torre Ugarte, *Supply Response Under the 1996 Farm Act and Implications for the U.S. Field Crops Sector* (Technical Bulletin No. 1888, ERS, USDA, July 2000, **http://www.ers.usda.gov/**); and James Barnes and Dennis Shields, *The Growth in U.S. Wheat Food Demand* (Wheat Situation and Outlook Yearbook, WHS-1998, **http://www.ers.usda.gov/**).

[10] For more information on past farm bills: **http://www.ers.usda.gov/farmbill/2008/**.

Demand

For many goods, demand is much more price elastic in the long run than in the short run. For one thing, it takes time for people to change their consumption habits. For example, even if the price of coffee rises sharply, the quantity demanded will fall only gradually as consumers begin to drink less. In addition, the demand for a good might be linked to the stock of another good that changes only slowly. For example, the demand for gasoline is much more elastic in the long run than in the short run. A sharply higher price of gasoline reduces the quantity demanded in the short run by causing motorists to drive less, but it has its greatest impact on demand by inducing consumers to buy smaller and more fuel-efficient cars. But because the stock of cars changes only slowly, the quantity of gasoline demanded falls only slowly. Figure 2.13(a) shows short-run and long-run demand curves for goods such as these.

DEMAND AND DURABILITY On the other hand, for some goods just the opposite is true—demand is more elastic in the short run than in the long run. Because these goods (automobiles, refrigerators, televisions, or the capital equipment purchased by industry) are *durable*, the total stock of each good owned by

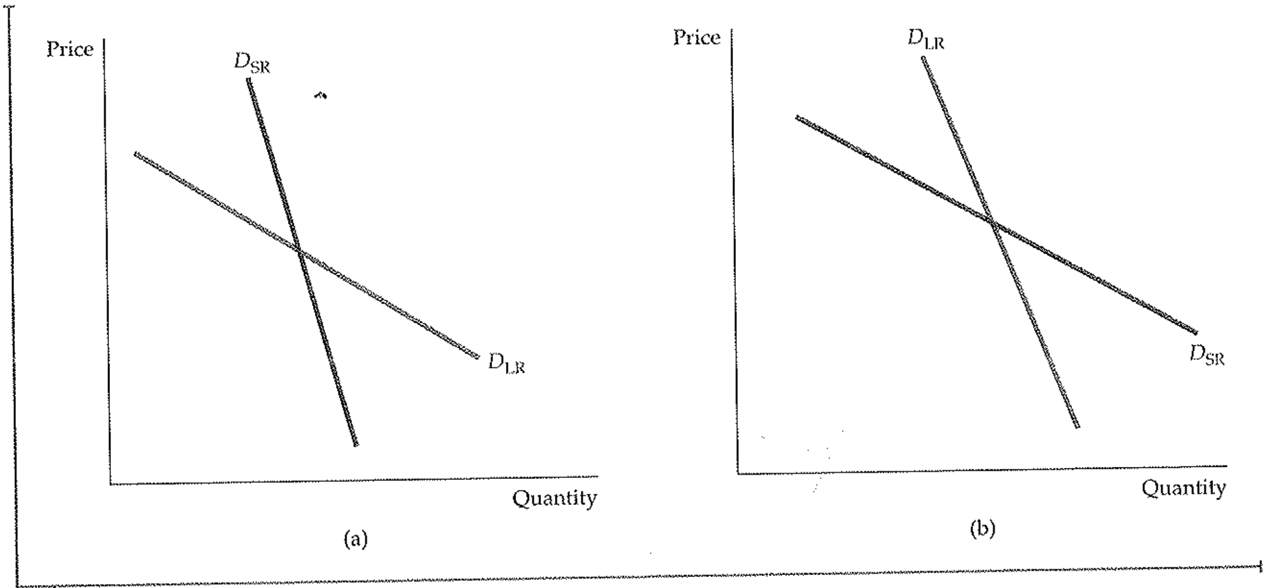


FIGURE 2.13
(a) GASOLINE: SHORT-RUN AND LONG-RUN DEMAND CURVES
(b) AUTOMOBILES: SHORT-RUN AND LONG-RUN DEMAND CURVES

(a) In the short run, an increase in price has only a small effect on the quantity of gasoline demanded. Motorists may drive less, but they will not change the kinds of cars they are driving overnight. In the longer run, however, because they will shift to smaller and more fuel-efficient cars, the effect of the price increase will be larger. Demand, therefore, is more elastic in the long run than in the short run. **(b)** The opposite is true for automobile demand. If price increases, consumers initially defer buying new cars; thus annual quantity demanded falls sharply. In the longer run, however, old cars wear out and must be replaced; thus annual quantity demanded picks up. Demand, therefore, is less elastic in the long run than in the short run.

consumers is large relative to annual production. As a result, a small change in the total stock that consumers want to hold can result in a large percentage change in the level of purchases.

Suppose, for example, that the price of refrigerators goes up 10 percent, causing the total stock of refrigerators that consumers want to hold to drop 5 percent. Initially, this will cause purchases of new refrigerators to drop much more than 5 percent. But eventually, as consumers' refrigerators depreciate (and units must be replaced), the quantity demanded will increase again. In the long run, the total stock of refrigerators owned by consumers will be about 5 percent less than before the price increase. In this case, while the long-run price elasticity of demand for refrigerators would be $-.05/.10 = -0.5$, the short-run elasticity would be much larger in magnitude.

Or consider automobiles. Although annual U.S. demand—new car purchases—is about 10 to 12 million, the stock of cars that people own is around 130 million. If automobile prices rise, many people will delay buying new cars. The quantity demanded will fall sharply, even though the total stock of cars that consumers might want to own at these higher prices falls only a small amount. Eventually, however, because old cars wear out and must be replaced, the quantity of new cars demanded picks up again. As a result, the long-run change in the quantity demanded is much smaller than the short-run change. Figure 2.13(b) shows demand curves for a durable good like automobiles.

INCOME ELASTICITIES Income elasticities also differ from the short run to the long run. For most goods and services—foods, beverages, fuel, entertainment, etc.—the income elasticity of demand is larger in the long run than in the short run. Consider the behavior of gasoline consumption during a period of strong economic growth during which aggregate income rises by 10 percent. Eventually people will increase gasoline consumption because they can afford to take more trips and perhaps own larger cars. But this change in consumption takes time, and demand initially increases only by a small amount. Thus, the long-run elasticity will be larger than the short-run elasticity.

For a durable good, the opposite is true. Again, consider automobiles. If aggregate income rises by 10 percent, the total stock of cars that consumers will want to own will also rise—say, by 5 percent. But this change means a much larger increase in *current purchases* of cars. (If the stock is 130 million, a 5-percent increase is 6.5 million, which might be about 60 to 70 percent of normal demand in a single year.) Eventually consumers succeed in increasing the total number of cars owned; after the stock has been rebuilt, new purchases are made largely to replace old cars. (These new purchases will still be greater than before because a larger stock of cars outstanding means that more cars need to be replaced each year.) Clearly, the short-run income elasticity of demand will be much larger than the long-run elasticity.

CYCLICAL INDUSTRIES Because the demands for durable goods fluctuate so sharply in response to short-run changes in income, the industries that produce these goods are quite vulnerable to changing macroeconomic conditions, and in particular to the business cycle—recessions and booms. Thus, these industries are often called **cyclical industries**—their sales patterns tend

• **cyclical industries** Industries in which sales tend to magnify cyclical changes in gross domestic product and national income.

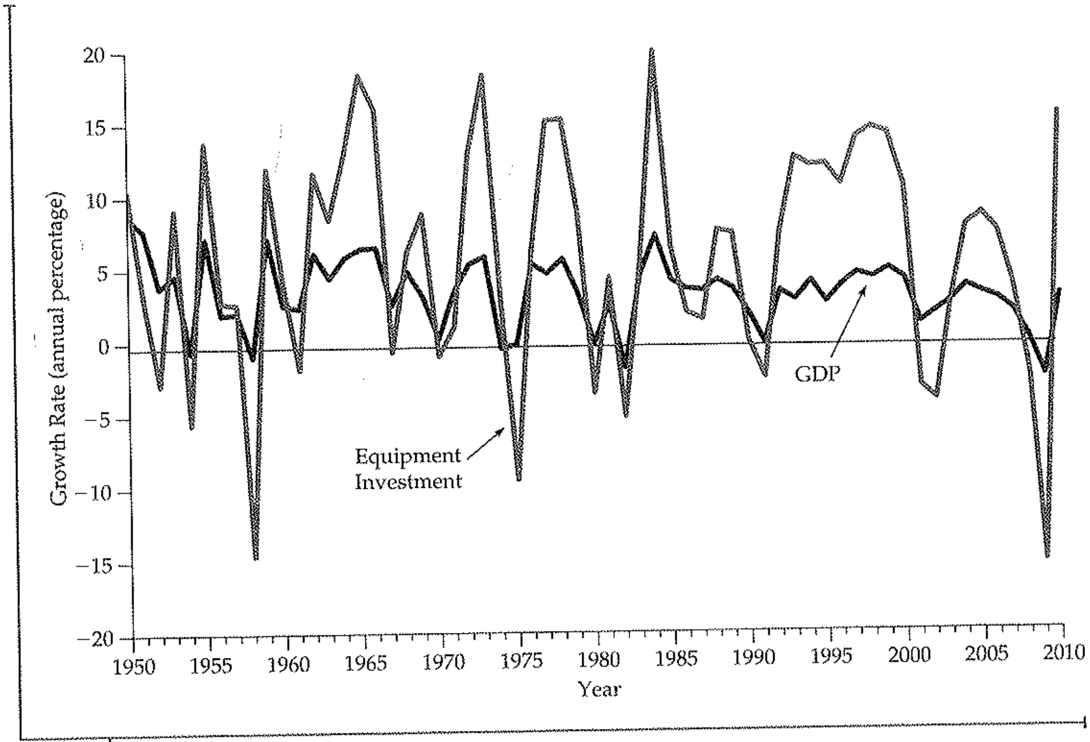


FIGURE 2.14
GDP AND INVESTMENT IN DURABLE EQUIPMENT

Annual growth rates are compared for GDP and investment in durable equipment. Because the short-run GDP elasticity of demand is larger than the long-run elasticity for long-lived capital equipment, changes in investment in equipment magnify changes in GDP. Thus capital goods industries are considered "cyclical."

to magnify cyclical changes in gross domestic product (GDP) and national income.

Figures 2.14 and 2.15 illustrate this principle. Figure 2.14 plots two variables over time: the annual real (inflation-adjusted) rate of growth of GDP and the annual real rate of growth of investment in producers' durable equipment (i.e., machinery and other equipment purchased by firms). Note that although the durable equipment series follows the same pattern as the GDP series, the changes in GDP are magnified. For example, in 1961–1966 GDP grew by at least 4 percent each year. Purchases of durable equipment also grew, but by much more (over 10 percent in 1963–1966). Equipment investment likewise grew much more quickly than GDP during 1993–1998. On the other hand, during the recessions of 1974–1975, 1982, 1991, 2001, and 2008, equipment purchases fell by much more than GDP.

Figure 2.15 also shows the real rate of growth of GDP, along with the annual real rates of growth of spending by consumers on durable goods (automobiles, appliances, etc.) and nondurable goods (food, fuel, clothing, etc.). Note that while both consumption series follow GDP, only the durable goods series tends to magnify changes in GDP. Changes in consumption of nondurables are roughly the same as changes in GDP, but changes in consumption of durables are usually several times larger. This is why companies

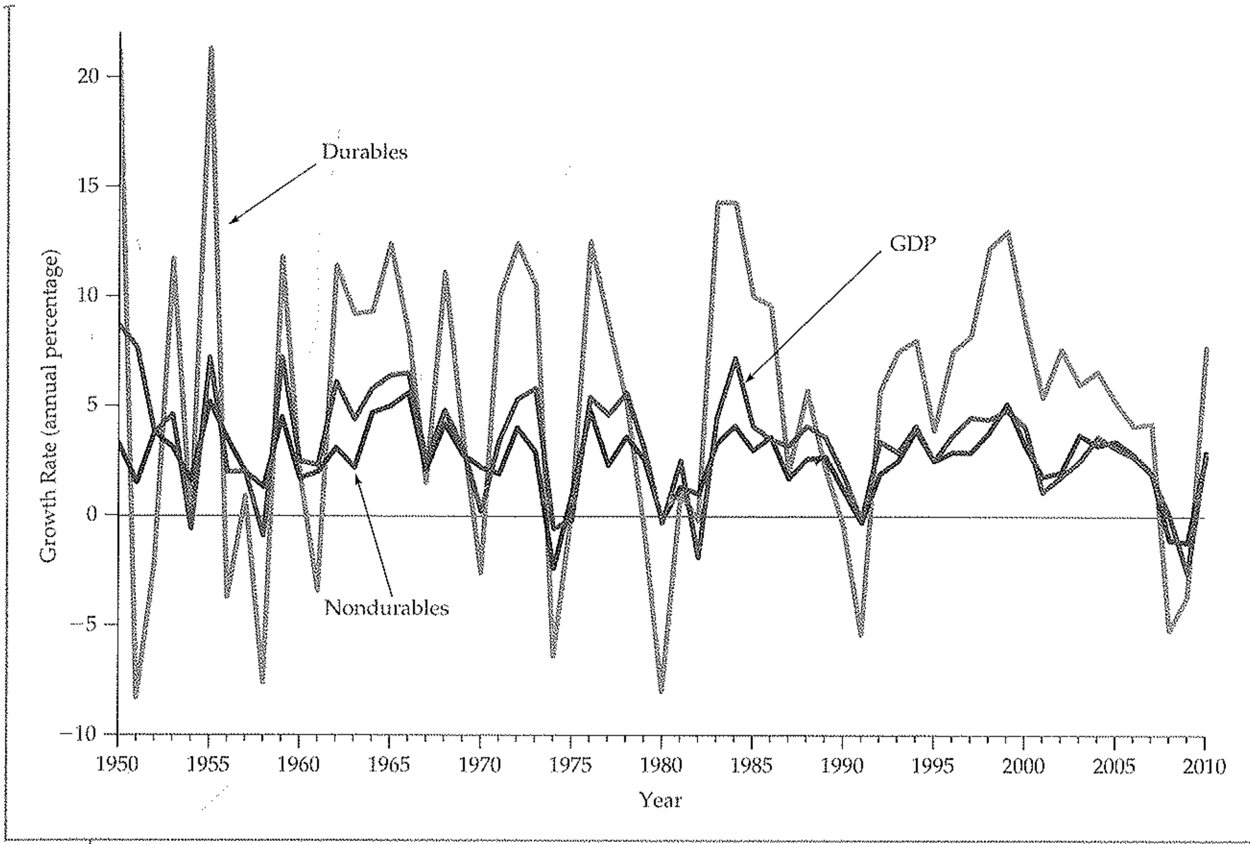


FIGURE 2.15
CONSUMPTION OF DURABLES VERSUS NONDURABLES

Annual growth rates are compared for GDP, consumer expenditures on durable goods (automobiles, appliances, furniture, etc.), and consumer expenditures on nondurable goods (food, clothing, services, etc.). Because the stock of durables is large compared with annual demand, short-run demand elasticities are larger than long-run elasticities. Like capital equipment, industries that produce consumer durables are "cyclical" (i.e., changes in GDP are magnified). This is not true for producers of nondurables.

such as General Motors and General Electric are considered "cyclical": Sales of cars and electrical appliances are strongly affected by changing macroeconomic conditions.

EXAMPLE 2.6 THE DEMAND FOR GASOLINE AND AUTOMOBILES

Gasoline and automobiles exemplify some of the different characteristics of demand discussed above. They are complementary goods—an increase in the price of one tends to reduce the demand for the other. In addition, their respective dynamic behaviors (long-run versus short-run elasticities) are just the opposite from each other. For gasoline, the long-run price and income elasticities are larger than the short-run elasticities; for automobiles, the reverse is true.

TABLE 2.1 DEMAND FOR GASOLINE

	NUMBER OF YEARS ALLOWED TO PASS FOLLOWING A PRICE OR INCOME CHANGE				
ELASTICITY	**1**	**2**	**3**	**5**	**10**
Price	–0.2	–0.3	–0.4	–0.5	–0.8
Income	0.2	0.4	0.5	0.6	1.0

There have been a number of statistical studies of the demands for gasoline and automobiles. Here we report elasticity estimates based on several that emphasize the dynamic response of demand.[11] Table 2.1 shows price and income elasticities of demand for gasoline in the United States for the short run, the long run, and just about everything in between.

Note the large differences between the long-run and the short-run elasticities. Following the sharp increases that occurred in the price of gasoline with the rise of the OPEC oil cartel in 1974, many people (including executives in the automobile and oil industries) claimed that the quantity of gasoline demanded would not change much—that demand was not very elastic. Indeed, for the first year after the price rise, they were right. But demand did eventually change. It just took time for people to alter their driving habits and to replace large cars with smaller and more fuel-efficient ones. This response continued after the second sharp increase in oil prices that occurred in 1979–1980. It was partly because of this response that OPEC could not maintain oil prices above $30 per barrel, and prices fell. The oil and gasoline price increases that occurred in 2005–2011 likewise led to a gradual demand response.

Table 2.2 shows price and income elasticities of demand for automobiles. Note that the short-run elasticities are much larger than the long-run

TABLE 2.2 DEMAND FOR AUTOMOBILES

	NUMBER OF YEARS ALLOWED TO PASS FOLLOWING A PRICE OR INCOME CHANGE				
ELASTICITY	**1**	**2**	**3**	**5**	**10**
Price	–1.2	–0.9	–0.8	–0.6	–0.4
Income	3.0	2.3	1.9	1.4	1.0

[11]For gasoline and automobile demand studies and elasticity estimates, see R. S. Pindyck, *The Structure of World Energy Demand* (Cambridge, MA: MIT Press, 1979); Carol Dahl and Thomas Sterner, "Analyzing Gasoline Demand Elasticities: A Survey," *Energy Economics* (July 1991); Molly Espey, "Gasoline Demand Revised: An International Meta-Analysis of Elasticities," *Energy Economics* (July 1998); David L. Greene, James R. Kahn, and Robert C. Gibson, "Fuel Economy Rebound Effects for U.S. Household Vehicles," *The Energy Journal* 20 (1999); Daniel Graham and Stephen Glaister, "The Demand for Automobile Fuel: A Survey of Elasticities," *Journal of Transport Economics and Policy* 36 (January 2002); and Ian Parry and Kenneth Small, "Does Britain or the United States Have the Right Gasoline Tax?" *American Economic Review* 95 (2005).

elasticities. It should be clear from the income elasticities why the automobile industry is so highly cyclical. For example, GDP fell 2 percent in real (inflation-adjusted) terms during the 1991 recession, but automobile sales fell by about 8 percent. Auto sales began to recover in 1993, and rose sharply between 1995 and 1999. During the 2008 recession, GDP fell by nearly 3 percent, and car and truck sales decreased by 21%. Sales began to recover in 2010, when they increased by nearly 10%.

Supply

Elasticities of supply also differ from the long run to the short run. For most products, long-run supply is much more price elastic than short-run supply: Firms face *capacity constraints* in the short run and need time to expand capacity by building new production facilities and hiring workers to staff them. This is not to say that the quantity supplied will not increase in the short run if price goes up sharply. Even in the short run, firms can increase output by using their existing facilities for more hours per week, paying workers to work overtime, and hiring some new workers immediately. But firms will be able to expand output much more when they have the time to expand their facilities and hire larger permanent workforces.

For some goods and services, short-run supply is completely inelastic. Rental housing in most cities is an example. In the very short run, there is only a fixed number of rental units. Thus an increase in demand only pushes rents up. In the longer run, and without rent controls, higher rents provide an incentive to renovate existing buildings and construct new ones. As a result, the quantity supplied increases.

For most goods, however, firms can find ways to increase output even in the short run—if the price incentive is strong enough. However, because various constraints make it costly to increase output rapidly, it may require large price increases to elicit small short-run increases in the quantity supplied. We discuss these characteristics of supply in more detail in Chapter 8.

SUPPLY AND DURABILITY For some goods, supply is more elastic in the short run than in the long run. Such goods are durable and can be recycled as part of supply if price goes up. An example is the *secondary supply* of metals: the supply from *scrap metal*, which is often melted down and refabricated. When the price of copper goes up, it increases the incentive to convert scrap copper into new supply, so that, initially, secondary supply increases sharply. Eventually, however, the stock of good-quality scrap falls, making the melting, purifying, and refabricating more costly. Secondary supply then contracts. Thus the long-run price elasticity of secondary supply is smaller than the short-run elasticity.

Figures 2.16(a) and 2.16(b) show short-run and long-run supply curves for primary (production from the mining and smelting of ore) and secondary copper production. Table 2.3 shows estimates of the elasticities for each component of supply and for total supply, based on a weighted average of the component elasticities.[12] Because secondary supply is only about 20 percent of total supply, the price elasticity of total supply is larger in the long run than in the short run.

[12] These estimates were obtained by aggregating the regional estimates reported in Franklin M. Fisher, Paul H. Cootner, and Martin N. Baily, "An Econometric Model of the World Copper Industry," *Bell Journal of Economics* 3 (Autumn 1972): 568–609.

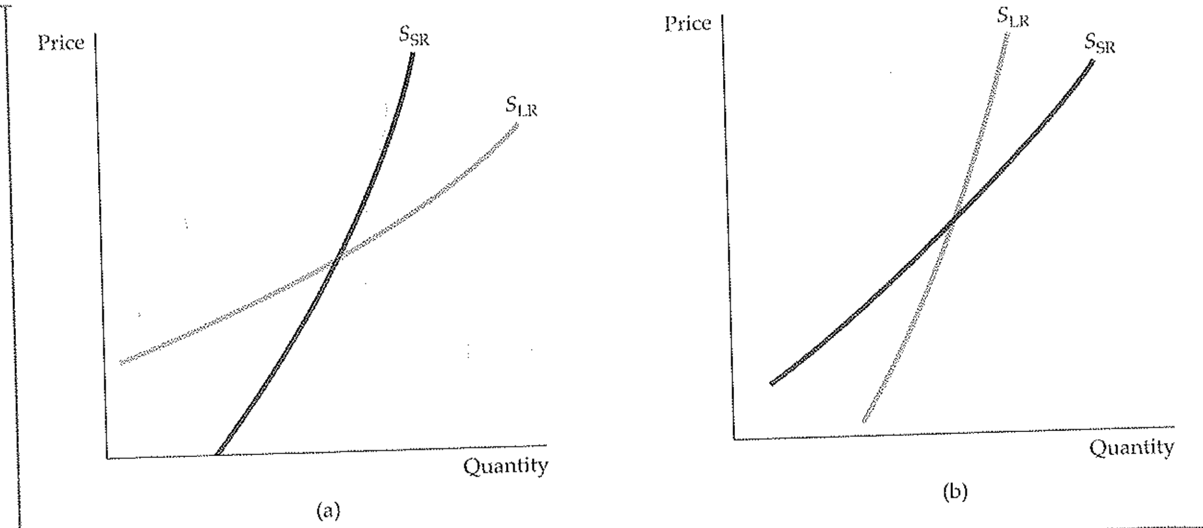


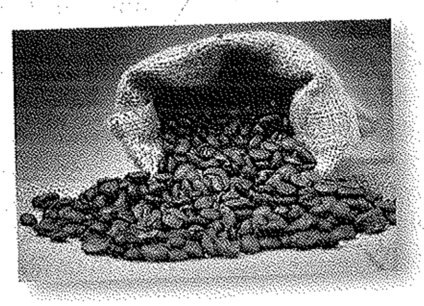
FIGURE 2.16
COPPER: SHORT-RUN AND LONG-RUN SUPPLY CURVES

Like that of most goods, the supply of primary copper, shown in part **(a)**, is more elastic in the long run. If price increases, firms would like to produce more but are limited by capacity constraints in the short run. In the longer run, they can add to capacity and produce more. Part **(b)** shows supply curves for secondary copper. If the price increases, there is a greater incentive to convert scrap copper into new supply. Initially, therefore, secondary supply (i.e., supply from scrap) increases sharply. But later, as the stock of scrap falls, secondary supply contracts. Secondary supply is therefore less elastic in the long run than in the short run.

TABLE 2.3 SUPPLY OF COPPER

PRICE ELASTICITY OF:	SHORT-RUN	LONG-RUN
Primary supply	0.20	1.60
Secondary supply	0.43	0.31
Total supply	0.25	1.50

EXAMPLE 2.7 THE WEATHER IN BRAZIL AND THE PRICE OF COFFEE IN NEW YORK



Droughts or subfreezing weather occasionally destroy or damage many of Brazil's coffee trees. Because Brazil is by far the world's largest coffee producer the result is a decrease in the supply of coffee and a sharp run-up in its price.

In July 1975, for example, a frost destroyed most of Brazil's 1976–1977 coffee crop. (Remember that it is winter in Brazil when it is summer in the northern hemisphere.) As Figure 2.17 shows, the price of a pound of coffee in New York went from 68 cents in 1975 to \$1.23 in 1976 and \$2.70 in 1977. Prices fell but then jumped again in 1986, after a seven-month drought in 1985 ruined much of Brazil's crop. Finally, starting in June 1994, freezing

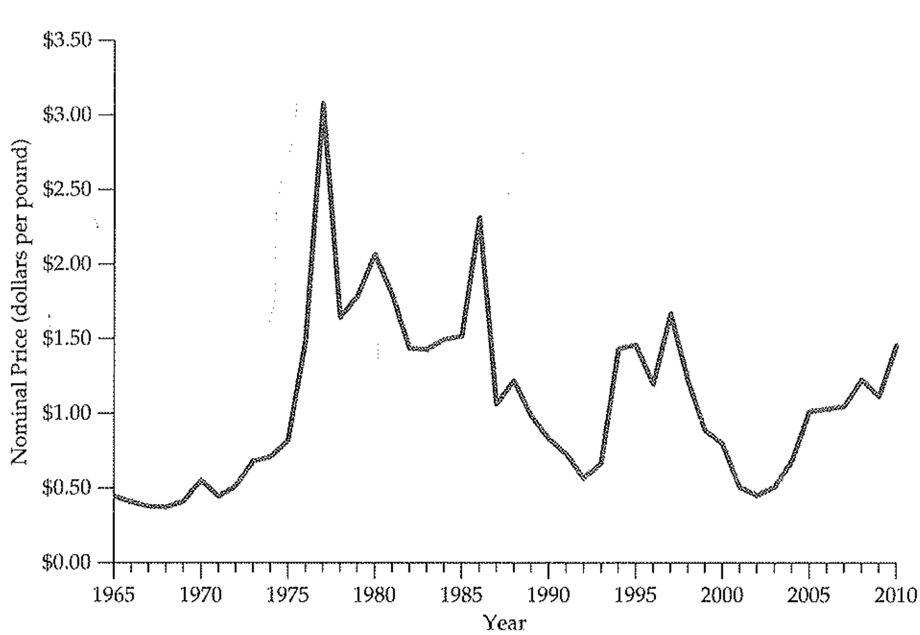


FIGURE 2.17
PRICE OF BRAZILIAN COFFEE

When droughts or freezes damage Brazil's coffee trees, the price of coffee can soar. The price usually falls again after a few years, as demand and supply adjust.

weather followed by a drought destroyed nearly half of Brazil's crop. As a result, the price of coffee in 1994–1995 was about double its 1993 level. By 2002, however, the price had dropped to its lowest level in 30 years. (Researchers predict that over the next 50 years, global warming may eliminate as much as 60 percent of Brazil's coffee-growing areas, resulting in a major decline in coffee production and an increase in prices. Should that happen, we will discuss it in the twentieth edition of this book.)

The important point in Figure 2.17 is that any run-up in price following a freeze or drought is usually short-lived. Within a year, price begins to fall; within three or four years, it returns to its earlier levels. In 1978, for example, the price of coffee in New York fell to $1.48 per pound, and by 1983, it had fallen in real (inflation-adjusted) terms to within a few cents of its prefreeze 1975 price.[13] Likewise, in 1987 the price of coffee fell to below its predrought 1984 level, and then continued declining until the 1994 freeze. After hitting a low of 45 cents per pound in 2002, coffee prices increased at an average rate of 17% per year, reaching $1.46—equal to the 1995 peak—in 2010. Brazilian coffee growers have worked to increase their production in the past decade, but bad weather has led to inconsistent crop yields.

Coffee prices behave this way because both demand and supply (especially supply) are much more elastic in the long run than in the short run. Figure 2.18 illustrates this fact. Note from part (a) of the figure that in the very short run (within one or two months after a freeze), supply is completely inelastic: There are simply a fixed number of coffee beans, some of which have been damaged by the frost. Demand is also relatively inelastic. As a result of the frost, the supply curve shifts to the left, and price increases sharply, from P_0 to P_1.

[13]During 1980, however, prices temporarily went just above $2.00 per pound as a result of export quotas imposed under the International Coffee Agreement (ICA). The ICA is essentially a cartel agreement implemented by the coffee-producing countries in 1968. It has been largely ineffective and has seldom had an effect on the price. We discuss cartel pricing in detail in Chapter 12.

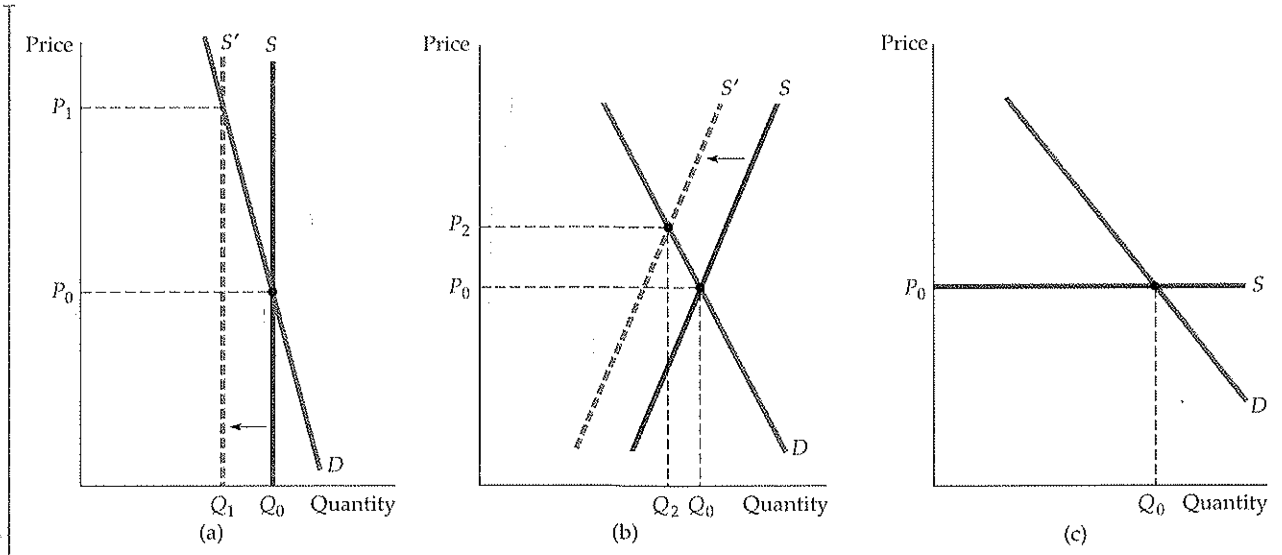


FIGURE 2.18
SUPPLY AND DEMAND FOR COFFEE

(a) A freeze or drought in Brazil causes the supply curve to shift to the left. In the short run, supply is completely inelastic; only a fixed number of coffee beans can be harvested. Demand is also relatively inelastic; consumers change their habits only slowly. As a result, the initial effect of the freeze is a sharp increase in price, from P_0 to P_1. **(b)** In the intermediate run, supply and demand are both more elastic; thus price falls part of the way back, to P_2. **(c)** In the long run, supply is extremely elastic; because new coffee trees will have had time to mature, the effect of the freeze will have disappeared. Price returns to P_0.

In the intermediate run—say, one year after the freeze—both supply and demand are more elastic, supply because existing trees can be harvested more intensively (with some decrease in quality), and demand because consumers have had time to change their buying habits. As part (b) shows, although the intermediate-run supply curve also shifts to the left, price has come down from P_1 to P_2. The quantity supplied has also increased somewhat from the short run, from Q_1 to Q_2. In the long run shown in part (c), price returns to its normal level because growers have had time to replace trees damaged by the freeze. The long-run supply curve, then, simply reflects the cost of producing coffee, including the costs of land, of planting and caring for the trees, and of a competitive rate of profit.[14]

*2.6 Understanding and Predicting the Effects of Changing Market Conditions

So far, our discussion of supply and demand has been largely qualitative. To use supply and demand curves to analyze and predict the effects of changing market conditions, we must begin attaching numbers to them. For example, to see how a 50-percent reduction in the supply of Brazilian coffee may affect the world price of coffee, we must determine actual supply and demand

[14]You can learn more about the world coffee market from the Foreign Agriculture Service of the U.S. Department of Agriculture by visiting their Web site at **http://www.fas.usda.gov/htp/coffee.asp**. Another good source of information is **http://www.nationalgeographic.com/coffee**.

curves and then calculate the shifts in those curves and the resulting changes in price.

In this section, we will see how to do simple "back of the envelope" calculations with linear supply and demand curves. Although they are often approximations of more complex curves, we use linear curves because they are easier to work with. It may come as a surprise, but one can do some informative economic analyses on the back of a small envelope with a pencil and a pocket calculator.

First, we must learn how to "fit" linear demand and supply curves to market data. (By this we do not mean *statistical fitting* in the sense of linear regression or other statistical techniques, which we will discuss later in the book.) Suppose we have two sets of numbers for a particular market: The first set consists of the price and quantity that generally prevail in the market (i.e., the price and quantity that prevail "on average," when the market is in equilibrium or when market conditions are "normal"). We call these numbers the *equilibrium price* and *quantity* and denote them by P^* and Q^*. The second set consists of the price elasticities of supply and demand for the market (at or near the equilibrium), which we denote by E_S and E_D, as before.

These numbers may come from a statistical study done by someone else; they may be numbers that we simply think are reasonable; or they may be numbers that we want to try out on a "what if" basis. Our goal is to *write down the supply and demand curves that fit (i.e., are consistent with) these numbers*. We can then determine numerically how a change in a variable such as GDP, the price of another good, or some cost of production will cause supply or demand to shift and thereby affect market price and quantity.

Let's begin with the linear curves shown in Figure 2.19. We can write these curves algebraically as follows:

$$\textit{Demand:} \quad Q = a - bP \tag{2.5a}$$

$$\textit{Supply:} \quad Q = c + dP \tag{2.5b}$$

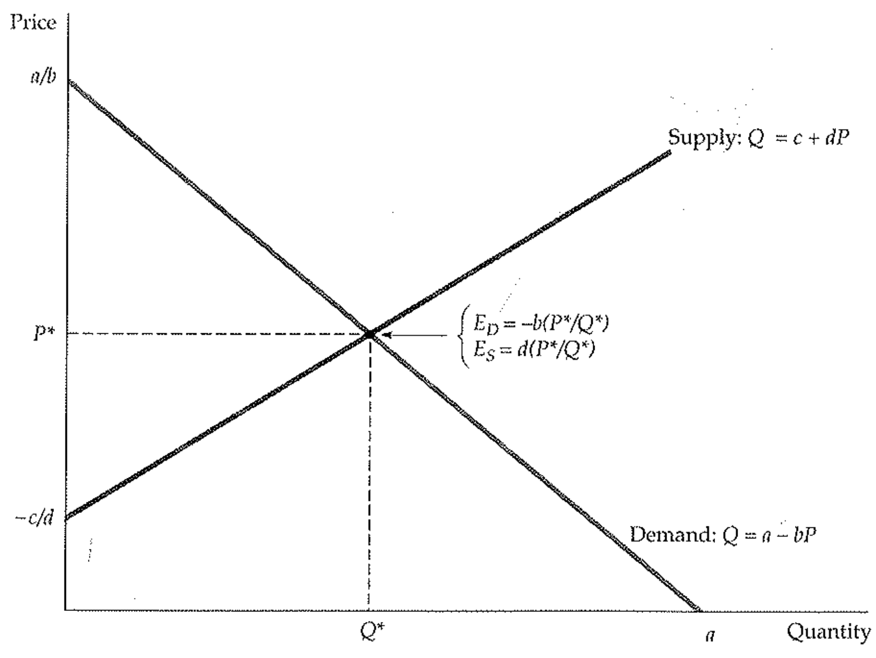


FIGURE 2.19
FITTING LINEAR SUPPLY AND DEMAND CURVES TO DATA

Linear supply and demand curves provide a convenient tool for analysis. Given data for the equilibrium price and quantity P^* and Q^*, as well as estimates of the elasticities of demand and supply E_D and E_S, we can calculate the parameters c and d for the supply curve and a and b for the demand curve. (In the case drawn here, $c < 0$.) The curves can then be used to analyze the behavior of the market quantitatively.

Our problem is to choose numbers for the constants a, b, c, and d. This is done, for supply and for demand, in a two-step procedure:

- ***Step 1:*** Recall that each price elasticity, whether of supply or demand, can be written as

$$E = (P/Q)(\Delta Q/\Delta P)$$

where $\Delta Q/\Delta P$ is the change in quantity demanded or supplied resulting from a small change in price. For linear curves, $\Delta Q/\Delta P$ is constant. From equations (2.5a) and (2.5b), we see that $\Delta Q/\Delta P = d$ for supply and $\Delta Q/\Delta P = -b$ for demand. Now, let's substitute these values for $\Delta Q/\Delta P$ into the elasticity formula:

$$\textit{Demand:}\quad E_D = -b(P^*/Q^*) \qquad \textbf{(2.6a)}$$

$$\textit{Supply:}\quad E_S = d(P^*/Q^*) \qquad \textbf{(2.6b)}$$

where P^* and Q^* are the equilibrium price and quantity for which we have data and to which we want to fit the curves. Because we have numbers for E_S, E_D, P^*, and Q^*, we can substitute these numbers in equations (2.6a) and (2.6b) and solve for b and d.

- ***Step 2:*** Since we now know b and d, we can substitute these numbers, as well as P^* and Q^*, into equations (2.5a) and (2.5b) and solve for the remaining constants a and c. For example, we can rewrite equation (2.5a) as

$$a = Q^* + bP^*$$

and then use our data for Q^* and P^*, together with the number we calculated in Step 1 for b, to obtain a.

Let's apply this procedure to a specific example: long-run supply and demand for the world copper market. The relevant numbers for this market are as follows:

Quantity $Q^* = 18$ million metric tons per year (mmt/yr)
Price $P^* = \$3.00$ per pound
Elasticity of suppy $E_S = 1.5$
Elasticity of demand $E_D = -0.5.$

(The price of copper has fluctuated during the past few decades between \$0.60 and more than \$4.00, but \$3.00 is a reasonable average price for 2008–2011).

We begin with the supply curve equation (2.5b) and use our two-step procedure to calculate numbers for c and d. The long-run price elasticity of supply is 1.5, $P^* = \$3.00$, and $Q^* = 18$.

- ***Step 1:*** Substitute these numbers in equation (2.6b) to determine d:

$$1.5 = d(3/18) = d/6$$

so that $d = (1.5)(6) = 9$.

- ***Step 2:*** Substitute this number for d, together with the numbers for P^* and Q^*, into equation (2.5b) to determine c:

$$18 = c + (9)(3.00) = c + 27$$

so that $c = 18 - 27 = -9$. We now know c and d, so we can write our supply curve:

$$\textit{Supply:} \quad Q = -9 + 9P$$

We can now follow the same steps for the demand curve equation (2.5a). An estimate for the long-run elasticity of demand is −0.5.[15] First, substitute this number, as well as the values for P^* and Q^*, into equation (2.6a) to determine b:

$$-0.5 = -b(3/18) = -b/6$$

so that $b = (0.5)(6) = 3$. Second, substitute this value for b and the values for P^* and Q^* in equation (2.5a) to determine a:

$$18 = a = (3)(3) = a - 9$$

so that $a = 18 + 9 = 27$. Thus, our demand curve is:

$$\textit{Demand:} \quad Q = 27 - 3P$$

To check that we have not made a mistake, let's set the quantity supplied equal to the quantity demanded and calculate the resulting equilibrium price:

$$\textit{Supply} = -9 + 9P = 27 - 3P = \textit{Demand}$$
$$9P + 3P = 27 + 9$$

or $P = 36/12 = 3.00$, which is indeed the equilibrium price with which we began.

Although we have written supply and demand so that they depend only on price, they could easily depend on other variables as well. Demand, for example, might depend on income as well as price. We would then write demand as

$$Q = a - bP + fI \tag{2.7}$$

where I is an index of the aggregate income or GDP. For example, I might equal 1.0 in a base year and then rise or fall to reflect percentage increases or decreases in aggregate income.

For our copper market example, a reasonable estimate for the long-run income elasticity of demand is 1.3. For the linear demand curve (2.7), we can then calculate f by using the formula for the income elasticity of demand: $E = (I/Q)(\Delta Q/\Delta I)$. Taking the base value of I as 1.0, we have

$$1.3 = (1.0/18)(f).$$

Thus $f = (1.3)(18)/(1.0) = 23.4$. Finally, substituting the values $b = 3$, $f = 23.4$, $P^* = 3.00$, and $Q^* = 18$ into equation (2.7), we can calculate that a must equal 3.6.

[15] See Claudio Agostini, "Estimating Market Power in the U.S. Copper Industry," *Review of Industrial Organization* 28 (2006), 17–39.

We have seen how to fit linear supply and demand curves to data. Now, to see how these curves can be used to analyze markets, let's look at Example 2.8, which deals with the behavior of copper prices, and Example 2.9, which concerns the world oil market.

EXAMPLE 2.8 THE BEHAVIOR OF COPPER PRICES

After reaching a level of about \$1.00 per pound in 1980, the price of copper fell sharply to about 60 cents per pound in 1986. In real (inflation-adjusted) terms, this price was even lower than during the Great Depression 50 years earlier. Prices increased in 1988–1989 and in 1995, largely as a result of strikes by miners in Peru and Canada that disrupted supplies, but then fell again from 1996 through 2003. Prices increased sharply, however, between 2003 and 2007, and while copper fell along with many other commodities during the 2008–2009 recession, the price of copper had recovered by early 2010. Figure 2.20 shows the behavior of copper prices from 1965 to 2011 in both real and nominal terms.

Worldwide recessions in 1980 and 1982 contributed to the decline of copper prices; as mentioned above, the income elasticity of copper demand is about 1.3. But copper demand did not pick up as the industrial economies recovered during the mid-1980s. Instead, the 1980s saw a steep decline in demand.

The price decline through 2003 occurred for two reasons. First, a large part of copper consumption is

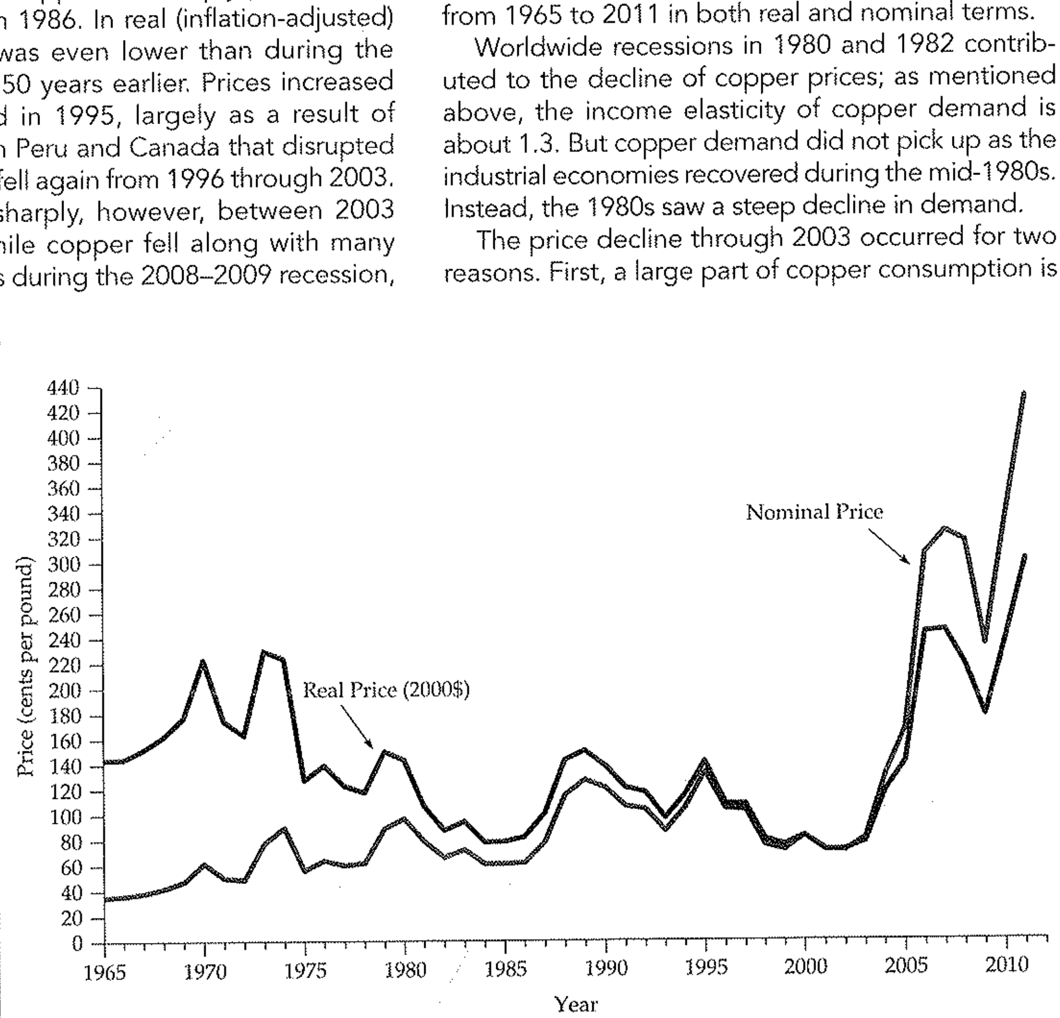


FIGURE 2.20
COPPER PRICES, 1965–2011

Copper prices are shown in both nominal (no adjustment for inflation) and real (inflation-adjusted) terms. In real terms, copper prices declined steeply from the early 1970s through the mid-1980s as demand fell. In 1988–1990, copper prices rose in response to supply disruptions caused by strikes in Peru and Canada but later fell after the strikes ended. Prices declined during the 1996–2002 period but then increased sharply starting in 2005.

for the construction of equipment for electric power generation and transmission. But by the late 1970s, the growth rate of electric power generation had fallen dramatically in most industrialized countries. In the United States, for example, the growth rate fell from over 6 percent per annum in the 1960s and early 1970s to less than 2 percent in the late 1970s and 1980s. This decline meant a big drop in what had been a major source of copper demand. Second, in the 1980s, other materials, such as aluminum and fiber optics, were increasingly substituted for copper.

Why did the price increase so sharply after 2003? First, the demand for copper from China and other Asian countries began increasing dramatically, replacing the demand from Europe and the U.S. Chinese copper consumption, for example, has nearly tripled since 2001. Second, because prices had dropped so much from 1996 through 2003, producers in the U.S., Canada, and Chile closed unprofitable mines and cut production. Between 2000 and 2003, for example, U.S. mine production of copper declined by 23 percent.[16]

One might expect increasing prices to stimulate investments in new mines and increases in production, and that is indeed what has happened. Arizona, for example, experienced a copper boom as Phelps Dodge opened a major new mine in 2007.[17] By 2007, producers began to worry that prices would decline again, either as a result of these new investments or because demand from Asia would level off or even drop.

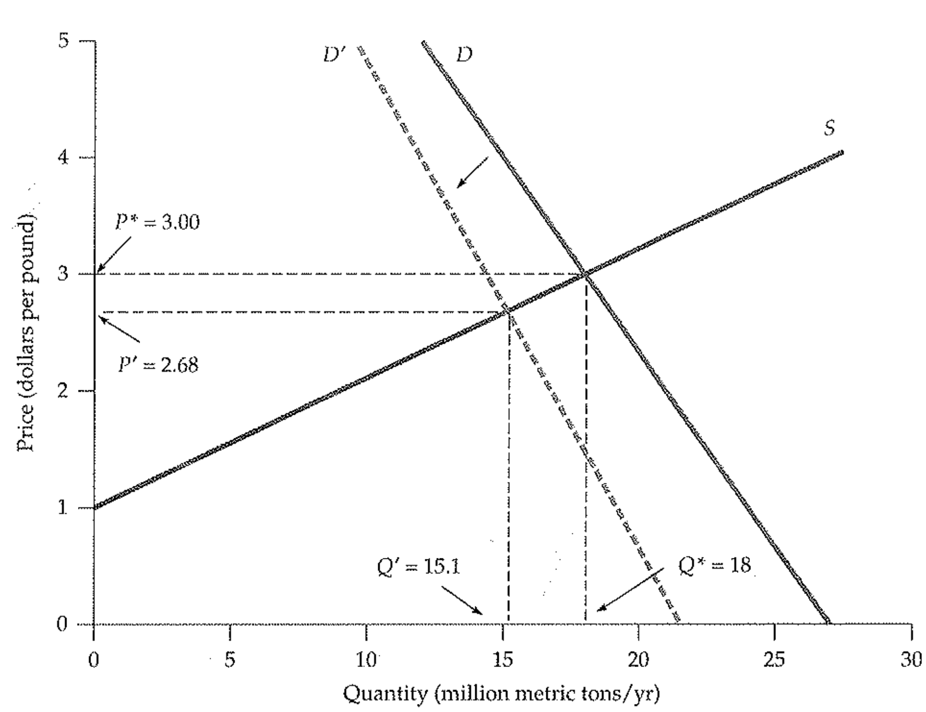


FIGURE 2.21
COPPER SUPPLY AND DEMAND

The shift in the demand curve corresponding to a 20-percent decline in demand leads to a 10.7-percent decline in price.

[16] Our thanks to Patricia Foley, Executive Director of the American Bureau of Metal Statistics, for supplying the data on China. Other data are from the Monthly Reports of the U.S. Geological Survey Mineral Resources Program—**http://minerals.usgs.gov/minerals/pubs/copper**.

[17] The boom created hundreds of new jobs, which in turn led to increases in housing prices: "Copper Boom Creates Housing Crunch," *The Arizona Republic*, July 12, 2007.

What would a decline in demand do to the price of copper? To find out, we can use the linear supply and demand curves that we just derived. Let's calculate the effect on price of a 20-percent decline in demand. Because we are not concerned here with the effects of GDP growth, we can leave the income term, fI, out of the demand equation.

We want to shift the demand curve to the left by 20 percent. In other words, we want the quantity demanded to be 80 percent of what it would be otherwise for every value of price. For our linear demand curve, we simply multiply the right–hand side by 0.8:

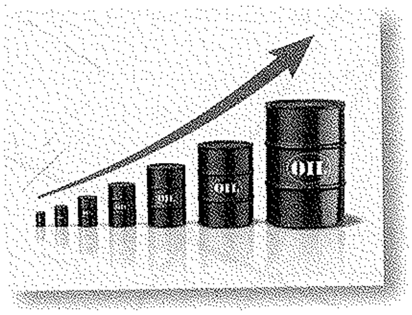
$$Q = (0.8)(27 - 3P) = 21.6 - 2.4P$$

Supply is again $Q = -9 + 9P$. Now we can equate the quantity supplied and the quantity demanded and solve for price:

$$-9 + 9P = 21.6 - 2.4P$$

or $P = 30.6/11.4 = \$2.68$ per pound. A decline in demand of 20 percent, therefore, entails a drop in price of roughly 32 cents per pound, or 10.7 percent.[18]

EXAMPLE 2.9 UPHEAVAL IN THE WORLD OIL MARKET



Since the early 1970s, the world oil market has been buffeted by the OPEC cartel and by political turmoil in the Persian Gulf. In 1974, by collectively restraining output, OPEC (the Organization of Petroleum Exporting Countries) pushed world oil prices well above what they would have been in a competitive market. OPEC could do this because it accounted for much of world oil production. During 1979–1980, oil prices shot up again, as the Iranian revolution and the outbreak of the Iran-Iraq war sharply reduced Iranian and Iraqi production. During the 1980s, the price gradually declined, as demand fell and competitive (i.e., non-OPEC) supply rose in response to price. Prices remained relatively stable during 1988–2001, except for a temporary spike in 1990 following the Iraqi invasion of Kuwait. Prices increased again in 2002–2003 as a result of a strike in Venezuela and then the war with Iraq that began in the spring of 2003. Oil prices continued to increase through the summer of 2008 as a result of rising demand in Asia and reductions in OPEC output. By the end of 2008, the recession had reduced demand around the world, leading prices to plummet 127% in six months. Between 2009 and 2011, oil prices have gradually recovered, partially buoyed by China's continuing growth. Figure 2.22 shows the world price of oil from 1970 to 2011, in both nominal and real terms.[19]

The Persian Gulf is one of the less stable regions of the world—a fact that has led to concern over the possibility of new oil supply disruptions and sharp increases in oil prices. What would happen to oil prices—in both the

[18]Note that because we have multiplied the demand function by 0.8—i.e., reduced the quantity demanded at every price by 20 percent—the new demand curve is not parallel to the old one. Instead, the curve rotates downward at its intersection with the price axis.

[19]For a nice overview of the factors that have affected world oil prices, see James D. Hamilton, "Understanding Crude Oil Prices," *The Energy Journal*, 2009, Vol. 30, pp. 179–206.

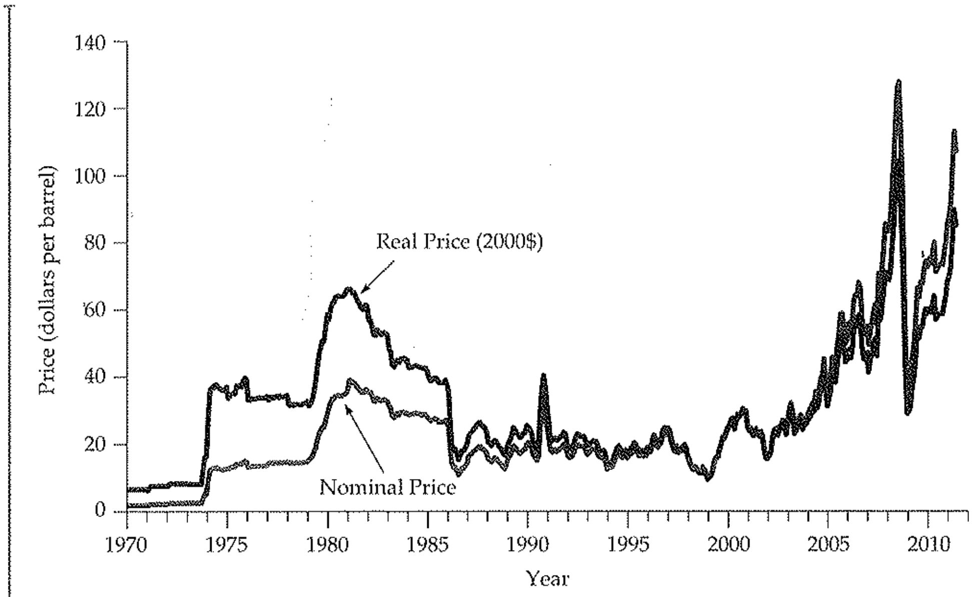


FIGURE 2.22
PRICE OF CRUDE OIL

The OPEC cartel and political events caused the price of oil to rise sharply at times. It later fell as supply and demand adjusted.

short run and longer run—if a war or revolution in the Persian Gulf caused a sharp cutback in oil production? Let's see how simple supply and demand curves can be used to predict the outcome of such an event.

Because this example is set in 2009–2011, all prices are measured in 2011 dollars. Here are some rough figures:

- 2009–2011 world price = $80 per barrel
- World demand and total supply = 32 billion barrels per year (bb/yr)
- OPEC supply = 13 bb/yr
- Competitive (non-OPEC) supply = 19 bb/yr

The following table gives price elasticity estimates for oil supply and demand:[20]

	SHORT RUN	LONG RUN
World demand:	−0.05	−0.30
Competitive supply:	0.05	0.30

[20]For the sources of these numbers and a more detailed discussion of OPEC oil pricing, see Robert S. Pindyck, "Gains to Producers from the Cartelization of Exhaustible Resources," *Review of Economics and Statistics* 60 (May 1978): 238–51; James M. Griffin and David J. Teece, *OPEC Behavior and World Oil Prices* (London: Allen and Unwin, 1982); and John C. B. Cooper, "Price Elasticity of Demand for Crude Oil: Estimates for 23 Countries," *Organization of the Petroleum Exporting Countries Review* (March 2003).

You should verify that these numbers imply the following for demand and competitive supply in the *short run*:

$$\textit{Short-run demand:} \quad D = 33.6 - .020P$$

$$\textit{Short-run competitive demand:} \quad S_C = 18.05 + 0.012P$$

Of course, *total* supply is competitive supply *plus* OPEC supply, which we take as constant at 13 bb/yr. Adding this 13 bb/yr to the competitive supply curve above, we obtain the following for the total short-run supply:

$$\textit{Short-run total supply:} \quad S_T = 31.05 + 0.012P$$

You should verify that the quantity demanded and the total quantity supplied are equal at an equilibrium price of $80 per barrel.

You should also verify that the corresponding demand and supply curves for the *long run* are as follows:

$$\textit{Long-run demand:} \quad D = 41.6 - 0.120P$$

$$\textit{Long-run competitive supply:} \quad S_C = 13.3 + 0.071P$$

$$\textit{Long-run total supply:} \quad S_T = 26.3 + 0.071P$$

Again, you can check that the quantities supplied and demanded equate at a price of $80.

Saudi Arabia is one of the world's largest oil producers, accounting for roughly 3 bb/yr, which is nearly 10 percent of total world production. What would happen to the price of oil if, because of war or political upheaval, Saudi Arabia stopped producing oil? We can use our supply and demand curves to find out.

For the *short run*, simply subtract 3 from short-run total supply:

$$\textit{Short-run demand:} \quad D = 33.6 - .020P$$

$$\textit{Short-run total demand:} \quad S_T = 28.05 + 0.012P$$

By equating this total quantity supplied with the quantity demanded, we can see that in the short run, the price will more than double to $173.44 per barrel. Figure 2.23 shows this supply shift and the resulting short-run increase in price. The initial equilibrium is at the intersection of S_T and D. After the drop in Saudi production, the equilibrium occurs where S'_T and D cross.

In the *long run*, however, things will be different. Because both demand and competitive supply are more elastic in the long run, the 3 bb/yr cut in oil production will no longer support such a high price. Subtracting 3 from long-run total supply and equating with long-run demand, we can see that the price will fall to $95.81, only $15.81 above the initial $80 price.

Thus, if Saudi Arabia suddenly stops producing oil, we should expect to see about a doubling in price. However, we should also expect to see the price gradually decline afterward, as demand falls and competitive supply rises.

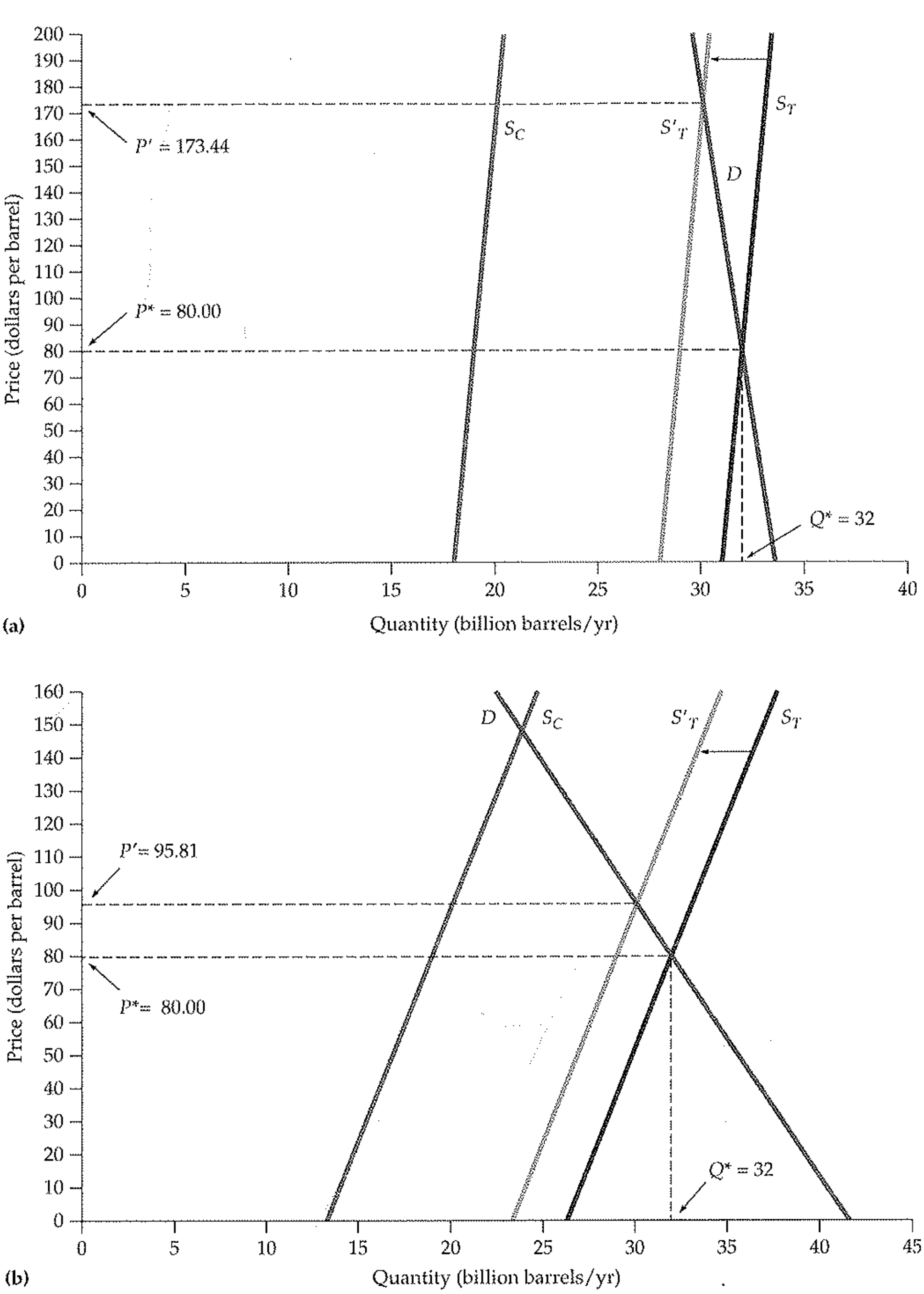


FIGURE 2.23
IMPACT OF SAUDI PRODUCTION CUT

The total supply is the sum of competitive (non-OPEC) supply and the 13 bb/yr of OPEC supply. Part **(a)** shows the short-run supply and demand curves. If Saudi Arabia stops producing, the supply curve will shift to the left by 3 bb/yr. In the short-run, price will increase sharply. Part **(b)** shows long-run curves. In the long run, because demand and competitive supply are much more elastic, the impact on price will be much smaller.

This is indeed what happened following the sharp decline in Iranian and Iraqi production in 1979–1980. History may or may not repeat itself, but if it does, we can at least predict the impact on oil prices.[21]

2.7 Effects of Government Intervention—Price Controls

In the United States and most other industrial countries, markets are rarely free of government intervention. Besides imposing taxes and granting subsidies, governments often regulate markets (even competitive markets) in a variety of ways. In this section, we will see how to use supply and demand curves to analyze the effects of one common form of government intervention: price controls. Later, in Chapter 9, we will examine the effects of price controls and other forms of government intervention and regulation in more detail.

Figure 2.24 illustrates the effects of price controls. Here, P_0 and Q_0 are the equilibrium price and quantity that would prevail without government regulation. The government, however, has decided that P_0 is too high and mandated that the price can be no higher than a maximum allowable *ceiling price*, denoted by P_{max}. What is the result? At this lower price, producers (particularly those with higher costs) will produce less, and the quantity supplied will drop to Q_1. Consumers, on the other hand, will demand more at this low price; they would like to purchase the quantity Q_2. Demand therefore exceeds supply, and a shortage develops—i.e., there is *excess demand*. The amount of excess demand is $Q_2 - Q_1$.

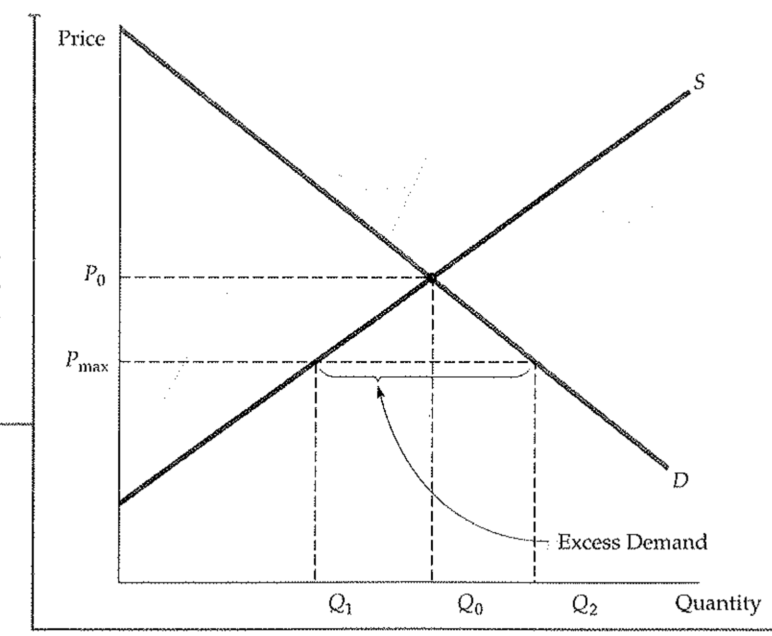


FIGURE 2.24
EFFECTS OF PRICE CONTROLS

Without price controls, the market clears at the equilibrium price and quantity P_0 and Q_0. If price is regulated to be no higher than P_{max}, the quantity supplied falls to Q_1, the quantity demanded increases to Q_2, and a shortage develops.

[21]You can obtain recent data and learn more about the world oil market by accessing the Web sites of the American Petroleum Institute at **www.api.org** or the U.S. Energy Information Administration at **www.eia.doe.gov**.

This excess demand sometimes takes the form of queues, as when drivers lined up to buy gasoline during the winter of 1974 and the summer of 1979. In both instances, the lines were the result of price controls; the government prevented domestic oil and gasoline prices from rising along with world oil prices. Sometimes excess demand results in curtailments and supply rationing, as with natural gas price controls and the resulting gas shortages of the mid-1970s, when industrial consumers closed factories because gas supplies were cut off. Sometimes it spills over into other markets, where it artificially increases demand. For example, natural gas price controls caused potential buyers of gas to use oil instead.

Some people gain and some lose from price controls. As Figure 2.24 suggests, producers lose: They receive lower prices, and some leave the industry. Some but not all consumers gain. While those who can purchase the good at a lower price are better off, those who have been "rationed out" and cannot buy the good at all are worse off. How large are the gains to the winners and how large are the losses to the losers? Do total gains exceed total losses? To answer these questions, we need a method to measure the gains and losses from price controls and other forms of government intervention. We discuss such a method in Chapter 9.

EXAMPLE 2.10 PRICE CONTROLS AND NATURAL GAS SHORTAGES

In 1954, the federal government began regulating the wellhead price of natural gas. Initially the controls were not binding; the ceiling prices were above those that cleared the market. But in about 1962, when these ceiling prices did become binding, excess demand for natural gas developed and slowly began to grow. In the 1970s, this excess demand, spurred by higher oil prices, became severe and led to widespread curtailments. Soon ceiling prices were far below prices that would have prevailed in a free market.[22]

Today, producers and industrial consumers of natural gas, oil, and other commodities are concerned that the government might respond, once again, with price controls if prices rise sharply. Let's calculate the likely impact of price controls on natural gas, based on market conditions in 2007.

Figure 2.25 shows the wholesale price of natural gas, in both nominal and real (2000 dollars) terms, from 1950 through 2007. The following numbers describe the U.S. market in 2007:

- The (free-market) wholesale price of natural gas was \$6.40 per mcf (thousand cubic feet);
- Production and consumption of gas were 23 Tcf (trillion cubic feet);
- The average price of crude oil (which affects the supply and demand for natural gas) was about \$50 per barrel.

A reasonable estimate for the price elasticity of supply is 0.2. Higher oil prices also lead to more natural gas production because oil and gas are often discovered and produced together; an estimate of the cross-price elasticity of supply is 0.1. As for demand, the price elasticity is about −0.5, and the cross-price elasticity with respect to oil price is about 1.5. You can verify that the following linear supply and demand curves fit these numbers:

$$\textit{Supply:}\quad Q = 15.90 + 0.72P_G + 0.05P_O$$

$$\textit{Demand:}\quad Q = 0.02 - 1.8P_G + 0.69P_O$$

[22]This regulation began with the Supreme Court's 1954 decision requiring the then Federal Power Commission to regulate wellhead prices on natural gas sold to interstate pipeline companies. These price controls were largely removed during the 1980s, under the mandate of the Natural Gas Policy Act of 1978. For a detailed discussion of natural gas regulation and its effects, see Paul W. MacAvoy and Robert S. Pindyck, *The Economics of the Natural Gas Shortage* (Amsterdam: North-Holland, 1975); R. S. Pindyck, "Higher Energy Prices and the Supply of Natural Gas," *Energy Systems and Policy* 2(1978): 177–209; and Arlon R. Tussing and Connie C. Barlow, *The Natural Gas Industry* (Cambridge, MA: Ballinger, 1984).

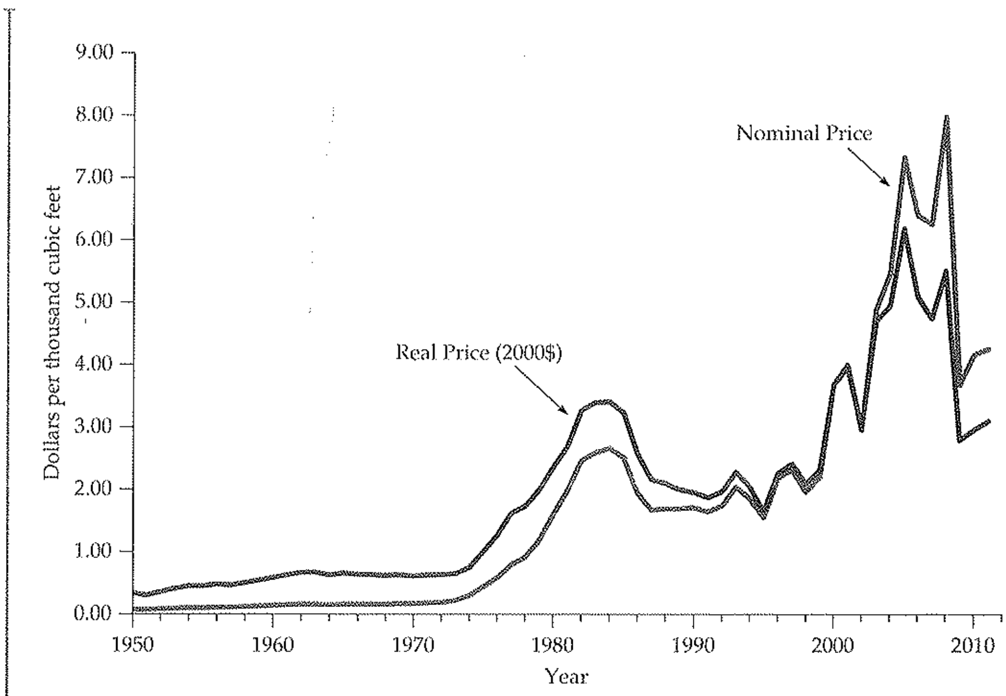


FIGURE 2.25
PRICE OF NATURAL GAS

Natural gas prices rose sharply after 2000, as did the prices of oil and other fuels.

where Q is the quantity of natural gas (in Tcf), P_G is the price of natural gas (in dollars per mcf), and P_O is the price of oil (in dollars per barrel). You can also verify, by equating the quantities supplied and demanded and substituting $50 for P_O, that these supply and demand curves imply an equilibrium free-market price of $6.40 for natural gas.

Suppose the government determines that the free-market price of $6.40 per mcf is too high, decides to impose price controls, and sets a maximum price of $3.00 per mcf. What impact would this have on the quantity of gas supplied and the quantity demanded?

Substitute $3.00 for P_G in both the supply and demand equations (keeping the price of oil, P_O, fixed at $50). You should find that the supply equation gives a quantity supplied of 20.6 Tcf and the demand equation a quantity demanded of 29.1 Tcf. Therefore, these price controls would create an excess demand (i.e., shortage) of 29.1 − 20.6 = 8.5 Tcf. In Example 9.1 we'll show how to measure the resulting gains and loses to producers and consumers.

SUMMARY

1. Supply-demand analysis is a basic tool of microeconomics. In competitive markets, supply and demand curves tell us how much will be produced by firms and how much will be demanded by consumers as a function of price.
2. The market mechanism is the tendency for supply and demand to equilibrate (i.e., for price to move to the market-clearing level), so that there is neither excess demand nor excess supply. The equilibrium price is the price that equates the quantity demanded with the quantity supplied.
3. Elasticities describe the responsiveness of supply and demand to changes in price, income, or other variables. For example, the price elasticity of demand measures

the percentage change in the quantity demanded resulting from a 1-percent increase in price.

4. Elasticities pertain to a time frame, and for most goods it is important to distinguish between short-run and long-run elasticities.
5. We can use supply-demand diagrams to see how shifts in the supply curve and/or demand curve can explain changes in the market price and quantity.
6. If we can estimate, at least roughly, the supply and demand curves for a particular market, we can calculate the market-clearing price by equating the quantity supplied with the quantity demanded. Also, if we know how supply and demand depend on other economic variables, such as income or the prices of other goods, we can calculate how the market-clearing price and quantity will change as these other variables change. This is a means of explaining or predicting market behavior.
7. Simple numerical analyses can often be done by fitting linear supply and demand curves to data on price and quantity and to estimates of elasticities. For many markets, such data and estimates are available, and simple "back of the envelope" calculations can help us understand the characteristics and behavior of the market.
8. When a government imposes price controls, it keeps the price below the level that equates supply and demand. A shortage develops; the quantity demanded exceeds the quantity supplied.

QUESTIONS FOR REVIEW

1. Suppose that unusually hot weather causes the demand curve for ice cream to shift to the right. Why will the price of ice cream rise to a new market-clearing level?
2. Use supply and demand curves to illustrate how each of the following events would affect the price of butter and the quantity of butter bought and sold: (a) an increase in the price of margarine; (b) an increase in the price of milk; (c) a decrease in average income levels.
3. If a 3-percent increase in the price of corn flakes causes a 6-percent decline in the quantity demanded, what is the elasticity of demand?
4. Explain the difference between a shift in the supply curve and a movement along the supply curve.
5. Explain why for many goods, the long-run price elasticity of supply is larger than the short-run elasticity.
6. Why do long-run elasticities of demand differ from short-run elasticities? Consider two goods: paper towels and televisions. Which is a durable good? Would you expect the price elasticity of demand for paper towels to be larger in the short run or in the long run? Why? What about the price elasticity of demand for televisions?
7. Are the following statements true or false? Explain your answers.
   a. The elasticity of demand is the same as the slope of the demand curve.
   b. The cross-price elasticity will always be positive.
   c. The supply of apartments is more inelastic in the short run than the long run.
8. Suppose the government regulates the prices of beef and chicken and sets them below their market-clearing levels. Explain why shortages of these goods will develop and what factors will determine the sizes of the shortages. What will happen to the price of pork? Explain briefly.
9. The city council of a small college town decides to regulate rents in order to reduce student living expenses. Suppose the average annual market-clearing rent for a two-bedroom apartment had been \$700 per month and that rents were expected to increase to \$900 within a year. The city council limits rents to their current \$700-per-month level.
   a. Draw a supply and demand graph to illustrate what will happen to the rental price of an apartment after the imposition of rent controls.
   b. Do you think this policy will benefit all students? Why or why not?
10. In a discussion of tuition rates, a university official argues that the demand for admission is completely price inelastic. As evidence, she notes that while the university has doubled its tuition (in real terms) over the past 15 years, neither the number nor quality of students applying has decreased. Would you accept this argument? Explain briefly. (*Hint*: The official makes an assertion about the demand for admission, but does she actually observe a demand curve? What else could be going on?)
11. Suppose the demand curve for a product is given by

$$Q = 10 - 2P + P_S$$

where P is the price of the product and P_S is the price of a substitute good. The price of the substitute good is \$2.00.
   a. Suppose $P = \$1.00$. What is the price elasticity of demand? What is the cross-price elasticity of demand?
   b. Suppose the price of the good, P, goes to \$2.00. Now what is the price elasticity of demand? What is the cross-price elasticity of demand?
12. Suppose that rather than the declining demand assumed in Example 2.8, a decrease in the cost of copper production causes the supply curve to shift to the right by 40 percent. How will the price of copper change?
13. Suppose the demand for natural gas is perfectly inelastic. What would be the effect, if any, of natural gas price controls?

EXERCISES

1. Suppose the demand curve for a product is given by $Q = 300 - 2P + 4I$, where I is average income measured in thousands of dollars. The supply curve is $Q = 3P - 50$.
   a. If $I = 25$, find the market-clearing price and quantity for the product.
   b. If $I = 50$, find the market-clearing price and quantity for the product.
   c. Draw a graph to illustrate your answers.
2. Consider a competitive market for which the quantities demanded and supplied (per year) at various prices are given as follows:

PRICE (DOLLARS)	DEMAND (MILLIONS)	SUPPLY (MILLIONS)
60	22	14
80	20	16
100	18	18
120	16	20

   a. Calculate the price elasticity of demand when the price is \$80 and when the price is \$100.
   b. Calculate the price elasticity of supply when the price is \$80 and when the price is \$100.
   c. What are the equilibrium price and quantity?
   d. Suppose the government sets a price ceiling of \$80. Will there be a shortage, and if so, how large will it be?
3. Refer to Example 2.5 (page 61) on the market for wheat. In 1998, the total demand for U.S. wheat was $Q = 3244 - 283P$ and the domestic supply was $Q_S = 1944 + 207P$. At the end of 1998, both Brazil and Indonesia opened their wheat markets to U.S. farmers. Suppose that these new markets add 200 million bushels to U.S. wheat demand. What will be the free-market price of wheat and what quantity will be produced and sold by U.S. farmers?
4. A vegetable fiber is traded in a competitive world market, and the world price is \$9 per pound. Unlimited quantities are available for import into the United States at this price. The U.S. domestic supply and demand for various price levels are shown as follows:

PRICE	U.S. SUPPLY (MILLION LBS)	U.S. DEMAND (MILLION LBS)
3	2	34
6	4	28
9	6	22
12	8	16
15	10	10
18	12	4

   a. What is the equation for demand? What is the equation for supply?
   b. At a price of \$9, what is the price elasticity of demand? What is it at a price of \$12?
   c. What is the price elasticity of supply at \$9? At \$12?
   d. In a free market, what will be the U.S. price and level of fiber imports?

*5. Much of the demand for U.S. agricultural output has come from other countries. In 1998, the total demand for wheat was $Q = 3244 - 283P$. Of this, total domestic demand was $Q_D = 1700 - 107P$, and domestic supply was $Q_S = 1944 + 207P$. Suppose the export demand for wheat falls by 40 percent.
   a. U.S. farmers are concerned about this drop in export demand. What happens to the free-market price of wheat in the United States? Do farmers have much reason to worry?
   b. Now suppose the U.S. government wants to buy enough wheat to raise the price to \$3.50 per bushel. With the drop in export demand, how much wheat would the government have to buy? How much would this cost the government?
6. The rent control agency of New York City has found that aggregate demand is $Q_D = 160 - 8P$. Quantity is measured in tens of thousands of apartments. Price, the average monthly rental rate, is measured in hundreds of dollars. The agency also noted that the increase in Q at lower P results from more three-person families coming into the city from Long Island and demanding apartments. The city's board of realtors acknowledges that this is a good demand estimate and has shown that supply is $Q_S = 70 + 7P$.
   a. If both the agency and the board are right about demand and supply, what is the free-market price? What is the change in city population if the agency sets a maximum average monthly rent of \$300 and all those who cannot find an apartment leave the city?
   b. Suppose the agency bows to the wishes of the board and sets a rental of \$900 per month on all apartments to allow landlords a "fair" rate of return. If 50 percent of any long-run increases in apartment offerings comes from new construction, how many apartments are constructed?
7. In 2010, Americans smoked 315 billion cigarettes, or 15.75 billion packs of cigarettes. The average retail price (including taxes) was about \$5.00 per pack. Statistical studies have shown that the price elasticity of demand is −0.4, and the price elasticity of supply is 0.5.
   a. Using this information, derive linear demand and supply curves for the cigarette market.
   b. In 1998, Americans smoked 23.5 billion packs of cigarettes, and the retail price was about \$2.00 per pack. The decline in cigarette consumption from 1998 to 2010 was due in part to greater public awareness of the health hazards from smoking, but was also due in part to the increase in price. Suppose that the *entire decline* was due to the

increase in price. What could you deduce from that about the price elasticity of demand?

8. In Example 2.8 we examined the effect of a 20-percent decline in copper demand on the price of copper, using the linear supply and demand curves developed in Section 2.6. Suppose the long-run price elasticity of copper demand were -0.75 instead of -0.5.
   a. Assuming, as before, that the equilibrium price and quantity are $P^* = \$3$ per pound and $Q^* = 18$ million metric tons per year, derive the linear demand curve consistent with the smaller elasticity.
   b. Using this demand curve, recalculate the effect of a 20-percent decline in copper demand on the price of copper.
9. In Example 2.8 (page 76), we discussed the recent increase in world demand for copper, due in part to China's rising consumption.
   a. Using the original elasticities of demand and supply (i.e., $E_S = 1.5$ and $E_D = -0.5$), calculate the effect of a 20-percent *increase* in copper demand on the price of copper.
   b. Now calculate the effect of this increase in demand on the equilibrium quantity, Q^*.
   c. As we discussed in Example 2.8, the U.S. production of copper declined between 2000 and 2003. Calculate the effect on the equilibrium price and quantity of *both* a 20-percent increase in copper demand (as you just did in part a) *and* of a 20-percent decline in copper supply.
10. Example 2.9 (page 78) analyzes the world oil market. Using the data given in that example:
   a. Show that the short-run demand and competitive supply curves are indeed given by

$$D = 33.6 - .020P$$
$$S_C = 18.05 + 0.012P$$

   b. Show that the long-run demand and competitive supply curves are indeed given by

$$D = 41.6 - 0.120P$$
$$S_C = 13.3 + 0.071P$$

   c. In Example 2.9 we examined the impact on price of a disruption of oil from Saudi Arabia. Suppose that instead of a decline in supply, OPEC production *increases* by 2 billion barrels per year (bb/yr) because the Saudis open large new oil fields. Calculate the effect of this increase in production on the price of oil in both the short run and the long run.
11. Refer to Example 2.10 (page 83), which analyzes the effects of price controls on natural gas.
   a. Using the data in the example, show that the following supply and demand curves describe the market for natural gas in 2005–2007:

$$\textit{Supply:}\quad Q = 15.90 + 0.72P_G + 0.05P_O$$
$$\textit{Demand:}\quad Q = 0.02 - 1.8P_G + 0.69P_O$$

   Also, verify that if the price of oil is \$50, these curves imply a free-market price of \$6.40 for natural gas.
   b. Suppose the regulated price of gas were \$4.50 per thousand cubic feet instead of \$3.00. How much excess demand would there have been?
   c. Suppose that the market for natural gas remained unregulated. If the price of oil had increased from \$50 to \$100, what would have happened to the free-market price of natural gas?

*12. The table below shows the retail price and sales for instant coffee and roasted coffee for two years.
   a. Using these data alone, estimate the short-run price elasticity of demand for roasted coffee. Derive a linear demand curve for roasted coffee.
   b. Now estimate the short-run price elasticity of demand for instant coffee. Derive a linear demand curve for instant coffee.
   c. Which coffee has the higher short-run price elasticity of demand? Why do you think this is the case?

YEAR	RETAIL PRICE OF INSTANT COFFEE ($/LB)	SALES OF INSTANT COFFEE (MILLION LBS)	RETAIL PRICE OF ROASTED COFFEE ($/LB)	SALES OF ROASTED COFFEE (MILLION LBS)
Year 1	10.35	75	4.11	820
Year 2	10.48	70	3.76	850