CHAPTER 2

DEMAND AND SUPPLY ANALYSIS

What Gives with the Price of Corn?

For years, the market for corn in the United States was dull and predictable. Prices hovered between $2.00 and $2.50 per bushel, and few expected them to rise much higher. But in the mid-1990s, as Figure 2.1 shows, the scenario changed. In late 1995, corn prices topped $3.00 per bushel, and by July 1996, prices were averaging nearly $4.50 per bushel! The upheaval created by rising corn prices was so great that experienced commodities traders warned investors to stay away from corn futures because prices had become too volatile.[1] Yet, as the 1990s came to a close, most news accounts of the corn market focused not on unprecedented high prices for corn, but on record low prices![2] After peaking in July 1996, corn prices fell consistently throughout 1997, 1998, and 1999. By late 1999, average corn prices had dipped to their lowest level in a decade, and were only slightly higher by the middle of 2003.

This story illustrates the vagaries of prices in a competitive market. Prices rise and fall in seemingly unpredictable ways, and there is little that individual participants (e.g., corn farmers, grain elevators, commodity traders) can do about it. However, we *can* understand *why* prices in the market change as they do. In the case of corn, the pattern of prices shown in Figure 2.1 can be traced to the interaction of some important changes in supply and demand conditions in the corn market in the 1990s. In the early 1990s, several years of bad weather devastated U.S. corn harvests. By early 1996, the amount of corn in storage for sales in future years had reached a record low. With the Asian economy booming and several countries around the world experiencing significant crop failures in 1996, demand for corn from overseas rose sharply and unexpectedly. With demand for U.S. corn up and the available supply in storage down, corn prices rose dramatically in the early summer of 1996.

But in 1997, the Asian economy slowed significantly, reducing the demand for corn from overseas. The global financial crisis of 1998 and the associated rise in the value of the dollar also reduced the demand for U.S. corn by countries such as Russia and Brazil. In the late 1990s, China, which had been the world's largest importer of agricultural commodities, undertook a major initiative to achieve self-sufficiency in basic foodstuffs. As a result, by 1999, China had shifted from being a leading importer of U.S. corn to a net exporter of its own corn. This, too, had a significant impact on the demand for U.S. corn in the last half of the 1990s. Finally, since 1996, the weather during the U.S. planting season (spring and summer) has generally been good, resulting in large harvests every year since 1996. By the end of 1999, the supply of corn in

[1] "Hedge Row: As Corn Prices Soar, A Futures Tactic Brings Rancor to Rural Towns," *The Wall Street Journal* (July 2, 1996), pp. A1, A6.

[2] See, for example, "Weather Goes Against the Grain: Farmers Sweat as Prices Fall to 27-Year Low," *Chicago Tribune* (July 7, 1999), Section 3, pp. 1 and 3.

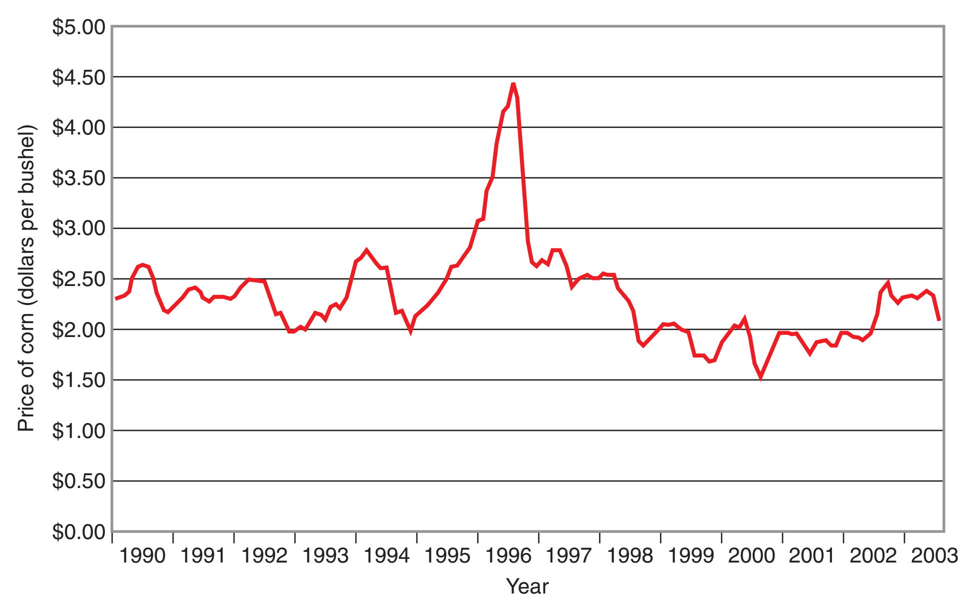


FIGURE 2.1 The Price of Corn in the United States, 1990–2003
The monthly price of corn received by farmers in the United States between January 1990 and July 2003; prices reached a peak of $4.43 per bushel in July 1996. *Source:* Feed Grain Yearbook, Economic Research Service, U.S. Department of Agriculture (ers.usda.gov/data/sdp/view).

storage in the United States was twice as large as it was at the end of 1995.[3] Increases in corn supplies, coupled with decreases in corn demand, explain why corn prices were so low between 1996 and 2001. The slight increase in the price of corn in 2002 and early 2003 reflects the decrease in the supply of corn in 2002, as production fell by about five percent.

The tools of supply and demand analysis that we introduced in Chapter 1 can help us understand the story that unfolded in the corn market over the past decade. In fact, they can help us understand the pattern of prices that prevail in a variety of markets, ranging from fresh-cut roses to DRAM chips for computers.

CHAPTER PREVIEW In this chapter, you will

- Learn about the three main building blocks of supply and demand analysis: demand curves, supply curves, and the concept of a market equilibrium.
- See what happens to market equilibrium when demand curves and supply curves shift.
- Learn about price elasticity of demand and how it varies along different types of demand curves.
- Study the relationship between price elasticity of demand and total revenue.

[3]Frederic Suris and Dennis Shields, "The Ag Sector: Yearend Wrap-up" *Agricultural Outlook*, *Economic Research Service*, U.S. Department of Agriculture (December 1999).

- Study the determinants of price elasticity of demand.
- Learn the distinction between market-level and brand-level price elasticities of demand.
- Study other elasticities, including income elasticity of demand, cross-price elasticity of demand, and price elasticity of supply.
- See how elasticities differ in the long run versus the short run.
- Study some "back-of-the-envelope" techniques for using limited quantitative information to predict how markets might respond to shifts in supply and demand.

2.1 DEMAND, SUPPLY, AND MARKET EQUILIBRIUM

Chapter 1 introduced equilibrium and comparative statics analysis. In this chapter, we apply those tools to the analysis of perfectly competitive markets. Perfectly competitive markets comprise large numbers of buyers and sellers. The transactions of any individual buyer or seller are so small in comparison to the overall volume of the good or service traded in the market that each buyer or seller "takes" the market price as given when making purchase or production decisions. For this reason, the model of perfect competition is often cited as a model of *price-taking* behavior.

Figure 2.2 illustrates the basic model of a perfectly competitive market. The horizontal axis depicts the total quantity Q of a particular good—in this case corn—that is supplied and demanded in this market. The vertical axis depicts the price P at which this good is sold. A market can be characterized along three dimensions: *commodity*—the product bought and sold (in Figure 2.2 this is corn); *geography*—the location in which purchases are being made (in Figure 2.2 this is the United States); and *time*—the period of time during which transactions are occurring (in Figure 2.2, this is the year 1996, when corn prices were the highest in a decade).

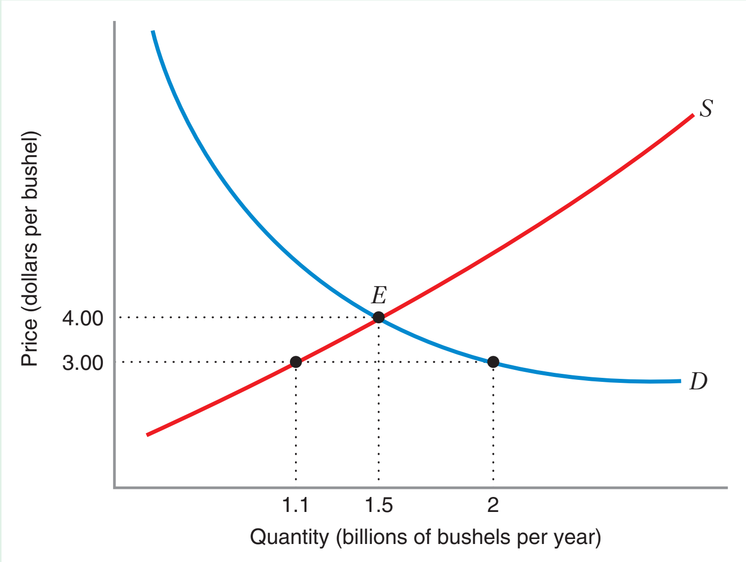


FIGURE 2.2 The Market for Corn in the United States, 1996
The curve labeled D is the demand curve for corn. The curve labeled S is the supply curve for corn. Point E, at which the two curves intersect, is the market equilibrium.

DEMAND CURVES

market demand curve A curve that shows us the quantity of goods that consumers are willing to buy at different prices.

The curve *D* in Figure 2.2 is the **market demand curve** for corn. It tells us the quantity of corn that buyers are willing to purchase at different prices. For example, the demand curve tells us that at a price of $3 per bushel, the annual demand for corn would be 2 billion bushels, while at a price of $4 per bushel, the annual demand for corn would be only 1.5 billion bushels.

derived demand Demand for a good that is derived from the production and sale of other goods.

direct demand Demand for a good that comes from the desire of buyers to directly consume the good itself.

Corn supplies are bought by companies (such as Archer Daniels Midland and General Mills) that process the corn into intermediate products (e.g., high fructose corn syrup or corn grits), which in turn are used to make final products (e.g., soft drinks or breakfast cereal). Part of the demand depicted in Figure 2.2 is **derived demand**—that is, it is derived from the production and sale of other goods. For example, the demand for high fructose corn syrup is derived from the demand for soft drinks in which it is used as a sweetener (instead of sugar). Corn is also purchased by brokers and wholesale distributors, who then sell it to retailers who then resell it to final consumers. Thus, another part of the demand for corn depicted in Figure 2.2 is **direct demand**—demand for the good itself. The demand curve *D* is a market demand curve in that it represents the aggregate demand for corn from all the corn purchasers in the U.S. market.

In Figure 2.2, we have drawn the demand curve with price on the vertical axis and quantity on the horizontal axis. This representation emphasizes another useful interpretation of the demand curve that we will return to in later chapters. The demand curve tells us the highest price that the "market will bear" for a given quantity or supply of output. Thus, in Figure 2.2, if suppliers of corn offered, in total, 2 billion bushels for sale, the highest price that the corn would fetch would be $3 per bushel.

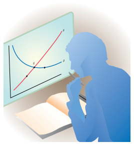
Other factors besides price affect the quantity of a good demanded. The prices of related goods, consumer incomes, consumer tastes, and advertising are among the factors that we expect would influence the demand for a typical product. However, the demand curve focuses only on the relationship between the price of the good and the quantity of the good demanded. When we draw the demand curve, we imagine that all other factors that affect the quantity demanded are fixed.

law of demand The inverse relationship between the price of a good and the quantity demanded, when all other factors that influence demand are held fixed.

The demand curve in Figure 2.2 slopes downward, indicating that the lower the price of corn, the greater the quantity of corn demanded, and the higher the price of corn, the smaller the quantity demanded. The inverse relationship between price and quantity demanded, *holding all other factors that influence demand fixed*, is called the **law of demand**. Countless studies of market demand curves confirm the inverse relationship between price and quantity demanded, which is why we call the relationship a *law*. Still, you might wonder about so-called luxury goods, such as perfume, designer labels, or crystal. It is alleged that some consumers purchase *more* of these goods at higher prices because a high price indicates superior quality.[4] However, these examples do not violate the law of demand because all of the other factors influencing demand for these goods are *not* held fixed while the price changes. Consumers' *perceptions* of the quality of these goods have also changed. If consumers' perceptions of quality could be held constant, then we would expect that consumers would purchase less of these luxury goods as the price goes up.

[4]Michael Schudson, *Advertising, The Uneasy Persuasion: Its Dubious Impact on American Society* (New York: Basic Books), pp. 113–114. 1984.

LEARNING-BY-DOING EXERCISE 2.1



Sketching a Demand Curve

Suppose the demand for new automobiles in the United States is described by the equation

$$Q^d = 5.3 - 0.1P \tag{2.1}$$

where Q^d is the number of new automobiles demanded per year (in millions) when P is the average price of an automobile (in thousands of dollars). (At this point, don't worry about the meaning of the constants in equations for demand or supply curves—in this case, 5.3 and -0.1.)

Problem

(a) What is the quantity of automobiles demanded per year when the average price of an automobile is \$15,000? When it is \$25,000? When it is \$35,000?

(b) Sketch the demand curve for automobiles. Does this demand curve obey the law of demand?

Solution

(a) To find the yearly demand for automobiles, given the average price per car, use equation (2.1):

Average Price per Car (P)	Using Equation (2.1)	Quantity Demanded (Q^d)
\$15,000	$Q^d = 5.3 - 0.1(15) = 3.8$	3.8 million cars
\$25,000	$Q^d = 5.3 - 0.1(25) = 2.8$	2.8 million cars
\$35,000	$Q^d = 5.3 - 0.1(35) = 1.8$	1.8 million cars

(b) Figure 2.3 shows the demand curve for automobiles. To sketch it, you can plot the combinations of prices and quantities that we found in part (a) and connect them with a

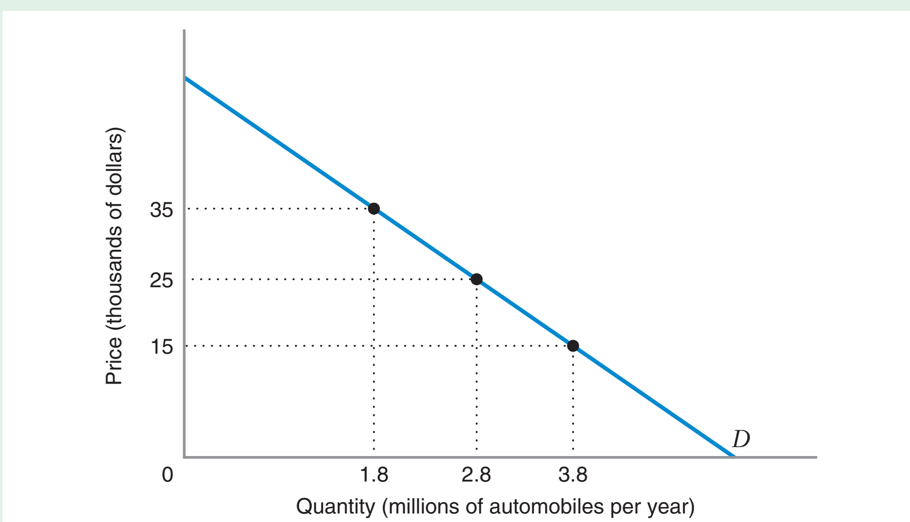


FIGURE 2.3 The U.S. Demand Curve for Automobiles
The law of demand holds in this market because the demand curve slopes downward.

line. The downward slope of the demand curve in Figure 2.3 tells us that as the price of automobiles goes up, consumers demand fewer automobiles.

Similar Problems: 2.1 and 2.2

SUPPLY CURVES

market supply curve A curve that shows us the total quantity of goods that their suppliers are willing to sell at different prices.

The curve labeled S in Figure 2.2 is the **market supply curve** for corn. It tells us the total quantity of corn that suppliers of corn are willing to sell at different prices. For example, the supply curve tells us that at a price of \$3 per bushel, 1.1 billion bushels of corn would be supplied in 1996, while at a price of \$4 per bushel, 1.5 billion bushels would be supplied in that year.

The supply of corn in the United States primarily comes from corn farmers around the country. The available supply in a given year consists of corn that is harvested in that year plus corn that has been stored from previous harvests. We should think of the supply curve S as being constructed from the sum of the supply curves of all individual suppliers of corn in the United States.

law of supply The positive relationship between price and quantity supplied, when all other factors that influence supply are held fixed.

factors of production Resources such as labor and raw materials that are used to produce a good.

The supply curve slopes upward, indicating that at higher prices, suppliers of corn are willing to offer more corn for sale than at lower prices. The positive relationship between price and quantity supplied is known as the **law of supply**. Studies of market supply curves confirm the positive relationship between the quantity supplied and the price, which is why we call the relationship a law.

As with demand, other factors besides price affect the quantity of a good that producers will supply to the market. For example, the prices of **factors of production**—resources such as labor and raw materials that are used to produce the good—will affect the quantity of the good that sellers are willing to supply. The prices of other goods that sellers produce could also affect the quantity supplied. For example, the supply of natural gas goes up when the price of oil goes up, because higher oil prices spur more oil production, and natural gas is a by-product of oil. When we draw a supply curve like the one in Figure 2.2, we imagine that all these other factors that affect the quantity supplied are held fixed.

LEARNING-BY-DOING EXERCISE 2.2

Sketching a Supply Curve

Suppose the yearly supply of wheat in Canada is described by the equation

$$Q^s = 0.15 + P \tag{2.2}$$

where Q^s is the quantity of wheat produced in Canada per year (in billions of bushels) when P is the average price of wheat (in dollars per bushel).

Problem

(a) What is the quantity of wheat supplied per year when the average price of wheat is \$2 per bushel? When the price is \$3? When the price is \$4?

(b) Sketch the supply curve for wheat. Does it obey the law of supply?

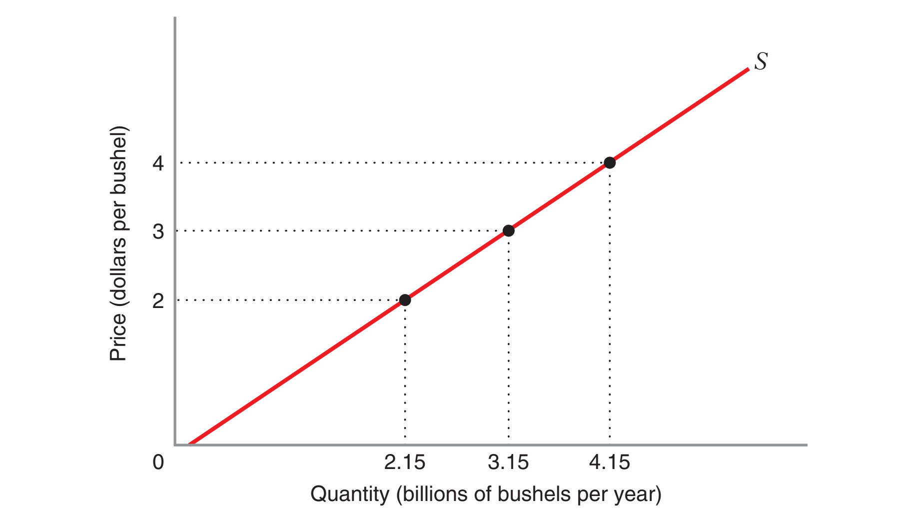


FIGURE 2.4 The Supply Curve for Wheat in Canada
The law of supply holds in this market because the supply curve slopes upward.

Solution

(a) To find the yearly supply of wheat, given the average price per bushel, use equation (2.2):

Average Price per Bushel (*P*)	Using Equation (2.2)	Quantity Supplied (Q^s)
\$2	$Q^s = 0.15 + 2 = 2.15$	2.15 million bushels
\$3	$Q^s = 0.15 + 3 = 3.15$	3.15 million bushels
\$4	$Q^s = 0.15 + 4 = 4.15$	4.15 million bushels

(b) Figure 2.4 shows the graph of this supply curve. We find it by plotting the prices and associated quantities from part (a) and connecting them with a line. The fact that the supply curve in Figure 2.4 slopes upward indicates that the law of supply holds.

MARKET EQUILIBRIUM

In Figure 2.2, the demand and supply curves intersect at point *E*, where the price is \$4 per bushel and the quantity is 1.5 billion bushels. At this point, the market is in **equilibrium** (the quantity demanded equals the quantity supplied, so the market clears). As we discussed in Chapter 1, an equilibrium is a point at which there is no tendency for the market price to change as long as exogenous variables (e.g., rainfall, national income) remain unchanged. At any price other than the equilibrium price, pressures exist for the price to change. For example, as Figure 2.5 shows, if the price of corn is \$5 per bushel, there is **excess supply**—the quantity supplied at that price (2 billion bushels) exceeds the quantity demanded (1.1 billion bushels). The fact that suppliers of corn cannot sell as much as they would like creates pressure for the price to go down. As the price falls, the quantity demanded goes up, the quantity supplied goes down, and the market moves toward the equilibrium price of \$4 per bushel. If the price

equilibrium A point at which there is no tendency for the market price to change as long as exogenous variables remain unchanged.

excess supply A situation in which the quantity supplied at a given price exceeds the quantity demanded.

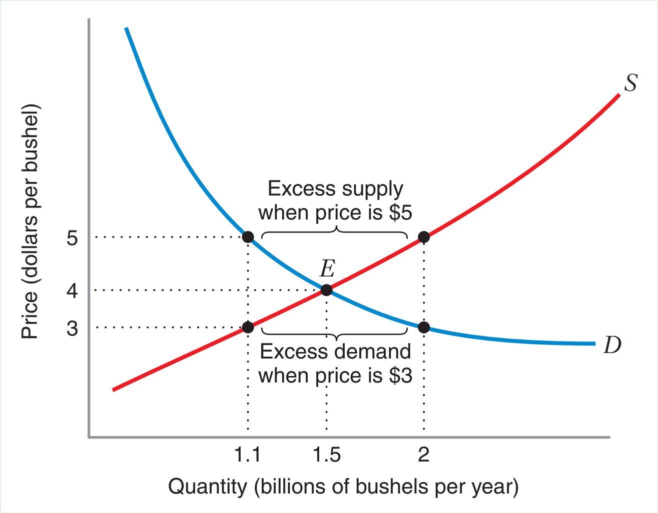
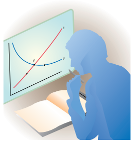


FIGURE 2.5 Excess Demand and Excess Supply in the Corn Market
If the price of corn were \$3, excess demand would result because 2 billion bushels would be demanded, but only 1.1 billion bushels would be supplied. If the price of corn were \$5 per bushel, excess supply would result because 2 billion bushels would be supplied but only 1.1 billion bushels would be demanded.

excess demand A situation in which the quantity demanded at a given price exceeds the quantity supplied.

of corn is \$3 per bushel, there is **excess demand**—the quantity demanded at that price (2 billion bushels) exceeds the quantity supplied (1.1 billion bushels). Buyers of corn cannot procure as much corn as they would like, and so there is pressure for the price to rise. As the price rises, the quantity supplied also rises, the quantity demanded falls, and the market moves toward the equilibrium price of \$4 per bushel.

LEARNING-BY-DOING EXERCISE 2.3



Calculating Equilibrium Price and Quantity

Suppose the market demand curve for cranberries in the United States is given by the equation $Q^d = 500 - 4P$, while the market supply curve for cranberries (when $P \geq 50$) is described by the equation $Q^s = -100 + 2P$, where P is the price of cranberries expressed in dollars per barrel, and quantity (Q^d or Q^s) is in millions of barrels per year.

Problem At what price and quantity is the market for cranberries in equilibrium? Show this equilibrium graphically.

Solution At equilibrium, the quantity supplied equals the quantity demanded, and we can use this relationship to solve for P: $Q^d = Q^s$, or $500 - 4P = -100 + 2P$, which implies $P = 100$. Thus, the equilibrium price is \$100 per barrel. We can then find the equilibrium quantity by substituting the equilibrium price into the equation for either the demand curve or the supply curve:

$$Q^d = 500 - 4(100) = 100$$
$$Q^s = -100 + 2(100) = 100$$

Thus, the equilibrium quantity is 100 million barrels per year. Figure 2.6 illustrates this equilibrium graphically.

Similar Problem: 2.3

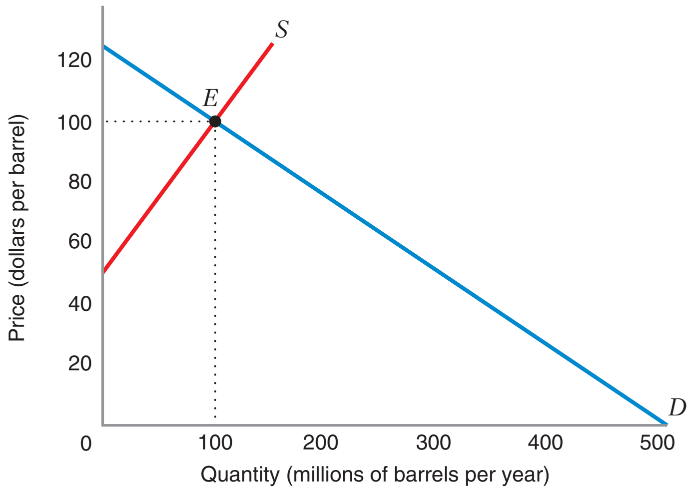


FIGURE 2.6 Equilibrium in the Market for Cranberries
The market equilibrium occurs at point *E*, where the demand and supply curves intersect. The equilibrium price is $100 per barrel and the equilibrium quantity is 100 million barrels of cranberries per year.

SHIFTS IN SUPPLY AND DEMAND

Shifts in *Either* Supply or Demand

The demand and supply curves discussed so far in this chapter were drawn under the assumption that all factors except for price that influence the quantity demanded and quantity supplied are fixed. In reality, however, these other factors are not fixed, and so the position of the demand and supply curves and thus the position of the market equilibrium depends on their values. Figures 2.7 and 2.8 illustrate how we can enrich our analysis to account for the effects of these other variables on the market equilibrium. These figures illustrate comparative statics analysis, which we discussed in Chapter 1. In both cases, we can explore how a change in an exogenous variable (e.g., consumer income or wage rates) changes the equilibrium values of the endogenous variables (price and quantity).

To do a comparative statics analysis of the market equilibrium, you first must determine how a particular exogenous variable affects demand or supply or both. You then represent changes in that variable by a shift in the demand curve, in the supply curve, or in both. For example, suppose that higher consumer incomes increase the demand for a particular good. The effect of higher disposable income on the market equilibrium is represented by a rightward shift in the demand curve (i.e., a shift away from the vertical axis), as shown in Figure 2.7.[5] This shift indicates that at any price the quantity demanded is greater than before. This shift moves the market equilibrium from point *A* to point *B*. The shift in demand due to higher income thus increases both the equilibrium price and the equilibrium quantity.

[5]The shift does not necessarily have to be parallel, as it is in Figure 2.7.

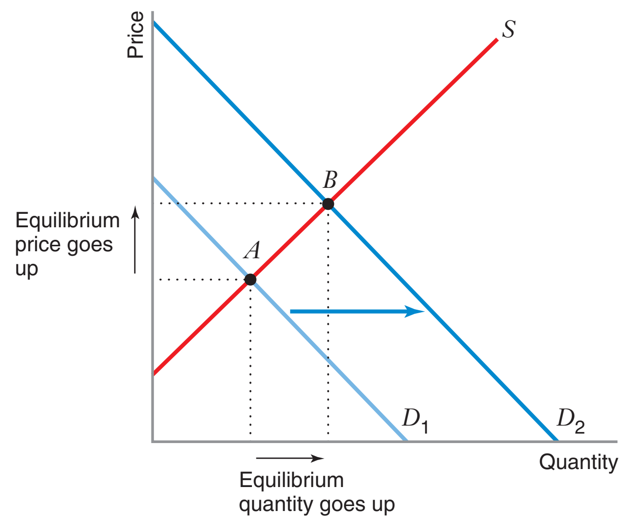


FIGURE 2.7 Shift in Demand Due to an Increase in Disposable Income
If an increase in consumers' disposable incomes increases demand for a particular good, the demand curve shifts rightward (i.e., away from the vertical axis) from D_1 to D_2, and the market equilibrium moves from point *A* to point *B*. Equilibrium price goes up, and equilibrium quantity goes up.

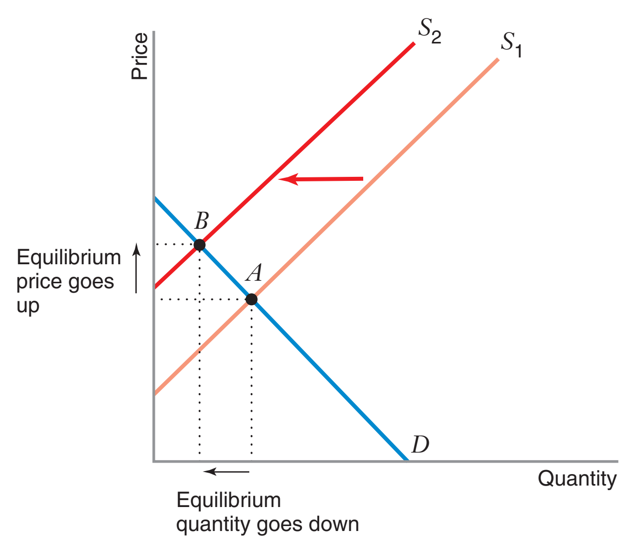


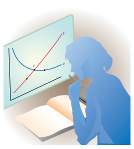
FIGURE 2.8 Shift in Supply Due to an Increase in the Price of Labor
An increase in the price of labor shifts the supply curve leftward (i.e., toward the vertical axis) from S_1 to S_2. The market equilibrium moves from point *A* to point *B*. Equilibrium price goes up, but equilibrium quantity goes down.

For another example, suppose wage rates for workers in a particular industry go up. Some firms might then reduce production levels because their costs have risen with the cost of labor. Some firms might even go out of business altogether. An increase in labor costs would shift the supply curve leftward (i.e., toward the vertical axis), as shown in Figure 2.8. This shift indicates that less product would be supplied at any price and the market equilibrium would move from point A to point B. The increase in the price of labor increases the equilibrium price and decreases the equilibrium quantity.

Figure 2.7 shows us that an increase in demand, coupled with an unchanged supply curve, results in a higher equilibrium price and a larger equilibrium quantity. Figure 2.8 shows that a decrease in supply, coupled with an unchanged demand curve, results in a higher equilibrium price and a smaller equilibrium quantity. By going through similar comparative statics analyses for a decrease in demand and an increase in supply, we can derive the four basic laws of supply and demand:

1. Increase in demand + unchanged supply curve = higher equilibrium price and larger equilibrium quantity.
2. Decrease in supply + unchanged demand curve = higher equilibrium price and smaller equilibrium quantity.
3. Decrease in demand + unchanged supply curve = lower equilibrium price and smaller equilibrium quantity.
4. Increase in supply + unchanged demand curve = lower equilibrium price and larger equilibrium quantity.

LEARNING-BY-DOING EXERCISE 2.4



Comparative Statics on the Market Equilibrium

Suppose that the U.S. demand for aluminum is given by the equation $Q^d = 500 - 50P + 10I$, where P is the price of aluminum expressed in dollars per ton and I is the average income per person in the United States (in thousands of dollars per year). Average income is an important determinant of the demand for automobiles and other products that use aluminum, and hence is a determinant of the demand for aluminum itself. Further suppose that the U.S. supply of aluminum (when $P \geq 8$) is given by the equation $Q^s = -400 + 50P$. In both the demand and supply functions, quantity is measured in millions of tons of aluminum per year.

Problem

(a) What is the market equilibrium price of aluminum when $I = 10$ (i.e., \$10,000 per year)?

(b) What happens to the demand curve if average income per person is only \$5,000 per year (i.e., $I = 5$ rather than $I = 10$). Calculate the impact of this demand shift on the market equilibrium price and quantity and then sketch the supply curve and the demand curves (when $I = 10$ and when $I = 5$) to illustrate this impact.

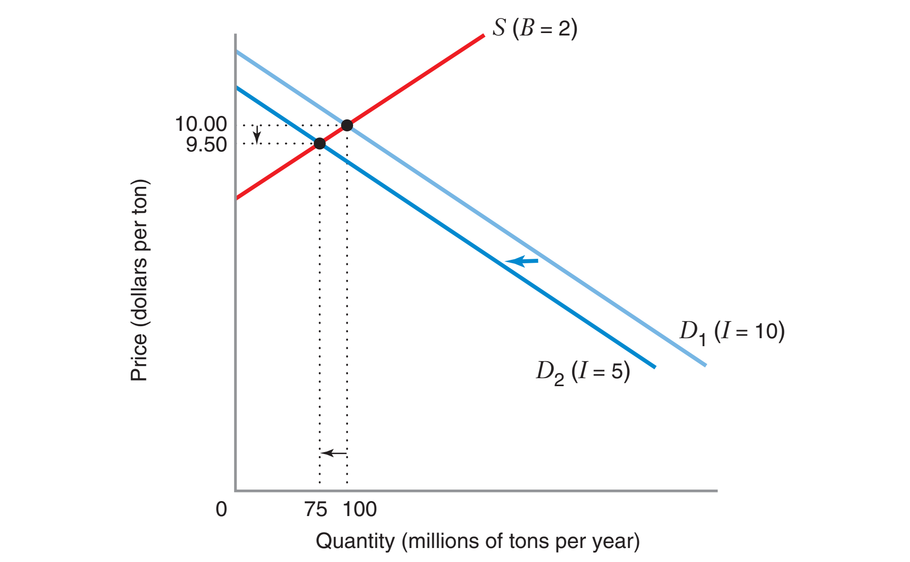


FIGURE 2.9 Equilibrium in the Market for Aluminum
The market equilibrium initially occurs at a price of $10 per ton and a quantity of 100 million tons. When average income goes down (i.e., when we move from $I = 10$ to $I = 5$), the demand curve for aluminum shifts leftward. The new equilibrium price is $9.50 per ton, and the new equilibrium quantity is 75 million tons.

Solution

(a) We substitute $I = 10$ into the demand equation to get the demand curve for aluminum: $Q^d = 600 - 50P$.

We then equate Q^d to Q^s to find the equilibrium price: $600 - 50P = -400 + 50P$, which implies $P = 10$. The equilibrium price is thus \$10 per ton. The equilibrium quantity is $Q = 600 - 50(10)$, or $Q = 100$. Thus, the equilibrium quantity is 100 million tons per year.

(b) The change in I creates a new demand curve that we find by substituting $I = 5$ into the demand equation shown above: $Q^d = 550 - 50P$. Figure 2.9 shows this demand curve as well as the demand curve for $I = 10$. As before, we equate Q^d to Q^s to find the equilibrium price: $550 - 50P = -400 + 50P$, which implies $P = 9.5$. The equilibrium price thus decreases from \$10 per ton to \$9.50 per ton. The equilibrium quantity is $Q = 550 - 50(9.50)$, or $Q = 75$. Thus, the equilibrium quantity decreases from 100 million tons per year to 75 million tons. Figure 2.9 shows this impact. Note that it is consistent with the third law of supply and demand: A decrease in demand coupled with an unchanged supply curve results in a lower equilibrium price and a smaller equilibrium quantity.

Similar Problem: 2.7

Shifts in *Both* Supply and Demand

So far, we have focused on what happens when either the supply curve or the demand curve shifts. But sometimes we can better understand the dynamics of prices and quantities in markets by exploring what happens when both supply and demand shift.

APPLICATION 2.1

The Valentine's Day Effect

If you have ever bought fresh-cut roses, you may have noticed that their price varies considerably during the year. In particular, the price you pay for fresh-cut roses—especially red roses—around Valentine's Day is usually three to five times higher than at other times during the year. Figure 2.10 illustrates this pattern by showing the prices and quantities of fresh-cut roses at two different times of the year: February and August in each of three years, 1991, 1992, and 1993.[6] Are the high prices of roses at Valentine's Day a result of a conspiracy among florists and rose growers to gouge romantic consumers? Probably not. This pricing behavior can best be understood as an application of comparative statics analysis.

Figure 2.11 depicts the market equilibrium in the U.S. market for fresh-cut roses in the early 1990s. During this period, wholesale prices for red hybrid tea roses were ordinarily about $0.20 per stem.[7] Every year, though, the market changes around Valentine's Day. During the days before Valentine's Day, demand for red roses increases dramatically, resulting in a rightward shift in the demand curve for roses from D_1 to D_2. This rightward shift occurs because around Valentine's Day, people who do not ordinarily purchase roses want to buy them for their spouses or sweethearts. The rightward shift in demand increases the equilibrium price to about $0.50 per stem. Even though the price is higher, the equilibrium quantity is also higher than it was before. This outcome does not contradict the law of demand. It reflects the fact that the Valentine's Day equilibrium occurs along a demand curve that is different from the demand curve before or after Valentine's Day.

Figure 2.11 explains why we would expect the prices of red roses to peak around Valentine's Day (the occurrence of Valentine's Day is an exogenous variable that strongly impacts the demand for red roses). The logic of Figure 2.11 also helps explain another aspect of the rose market: the prices of white and yellow roses. Their prices also go up around Valentine's Day, but by less than the prices of red roses. Overall, their prices show more stability than the prices of red roses because white and yellow roses are less popular on Valentine's Day and are used more for weddings and other special events. These events are spread more evenly throughout the year, so the demand curves for white and yellow roses fluctuate less dramatically than the demand curve for red roses. As a result, their equilibrium prices are more stable.

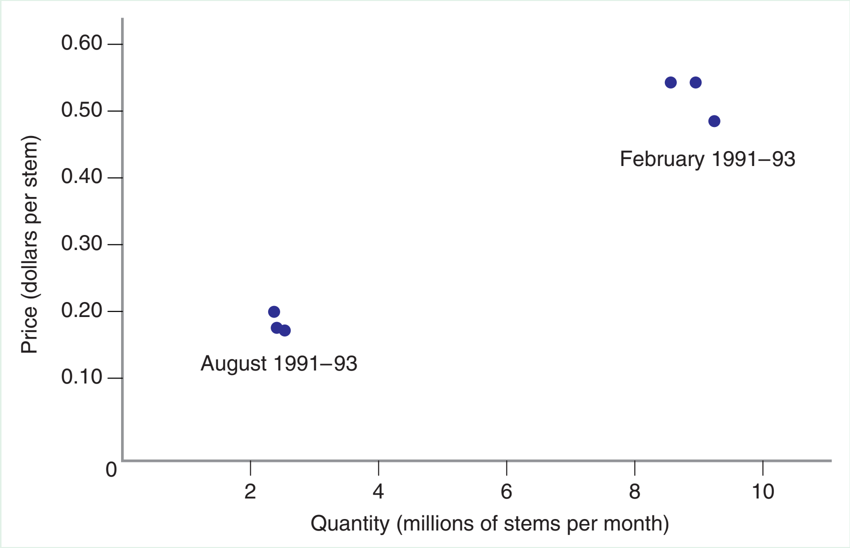


FIGURE 2.10 Prices and Quantities of Fresh-Cut Roses Prices and quantities of roses during 1991–1993 for the months of August and February—both are much higher in February than they are in August.

[6]The data in Figure 2.10 are derived from Tables 12 and 17 of "Fresh Cut Roses from Colombia and Ecuador," Publication 2766, International Trade Commission (March 1994). The data for February actually consist of the last two weeks of January and the first two weeks of February.

[7]These are wholesale prices (i.e., the prices that retail florists pay their suppliers), not the retail prices paid by the final consumer.

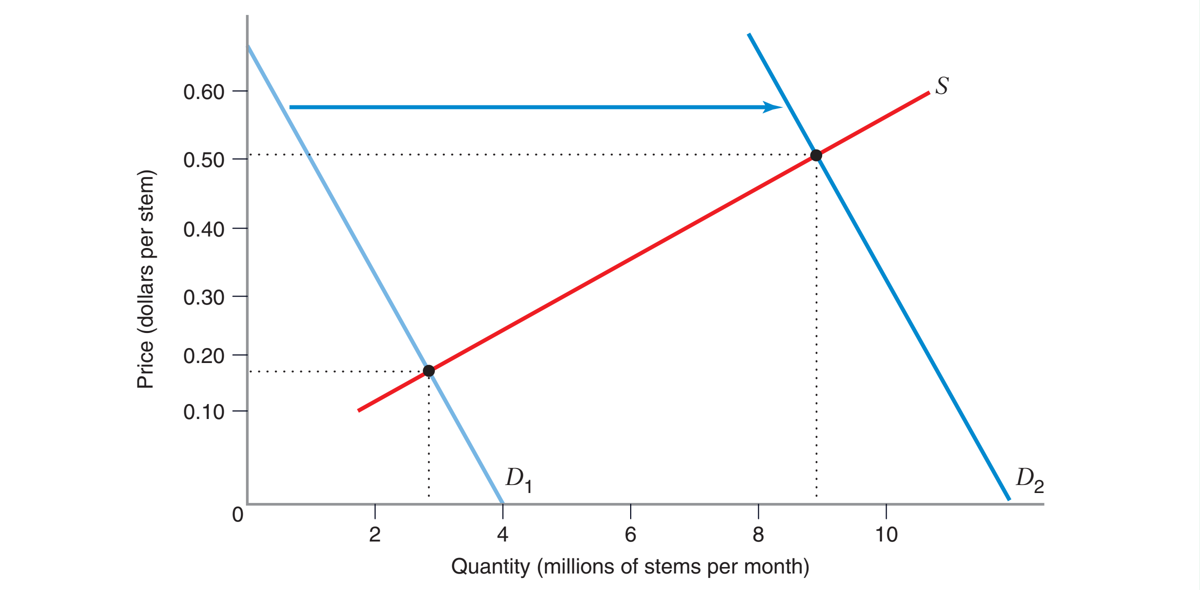
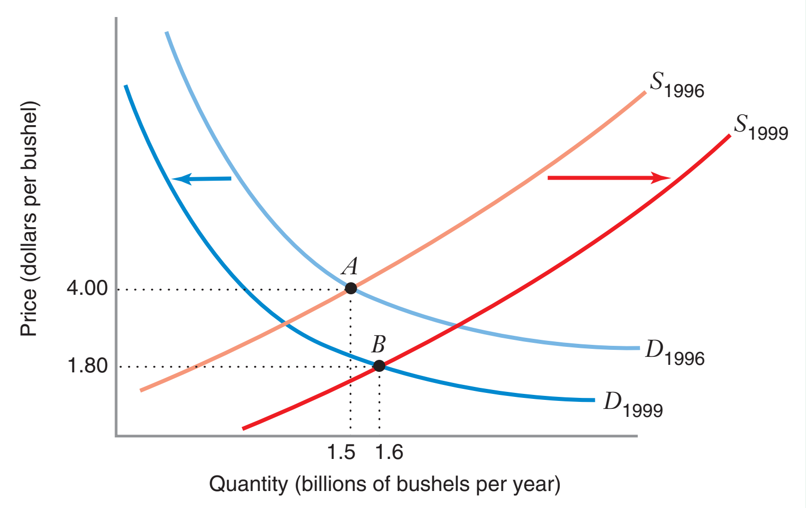


FIGURE 2.11 The Market for Fresh-Cut Roses
During "usual" months, the market for fresh-cut roses attains an equilibrium at a price of about \$0.20 per stem. However, during the weeks around Valentine's Day, the demand curve for roses shifts rightward, from D_1 to D_2, and the equilibrium price and quantity go up.

We return to the example of the U.S. corn market in the 1990s to illustrate this point. Figure 2.12 shows the difference between the equilibrium in the corn market in 1996 when prices reached \$4 per bushel (point *A*) and 1999 when prices fell below \$2 per bushel (point *B*). As we discussed in the introduction, the decrease in the price of

FIGURE 2.12 The U.S. Corn Market 1996–1999
The decrease in the U.S. corn price can be explained by the combined effect of a shift in supply and a shift in demand. In particular, the demand curve shifted leftward from D_{1996} to D_{1999}, while the supply curve shifted rightward from S_{1996} to S_{1999}, moving the equilibrium from point *A* to point *B*. The result was a decrease in the equilibrium price from \$4 per bushel to \$1.80 per bushel.



APPLICATION 2.2

A Chicken in Every Pot[8]

A *broiler* is a young chicken grown for its meat rather than for its eggs. Raising chickens for meat is, by the standards of U.S. agriculture, a relatively new industry. In the early 1900s, most farmers raised chickens for their eggs. Chicken was considered a luxury meat, one that was consumed on holidays or special days, such as the Sabbath. Herbert Hoover's 1928 promise, "A chicken in every pot," reflected the upscale status that chicken meat had in the United States at the time. But World War II was a boon for the chicken business. Beef was rationed, and consumers turned to chicken as a substitute. The demand created during World War II continued to grow after the war. In 1940, the per capita quantity of chicken consumed was just 2 pounds per year.[9] By 1945, it had grown to 5 pounds. From the 1960s through the 1980s, demand for chicken meat exploded. By 1990, with a per capita consumption of 70.1 pounds, chicken was the most consumed meat in the United States.

Figure 2.13 illustrates the real price[10] and the per capita quantity of broilers over the period 1950–1990. The figure documents a dramatic decline in real broiler prices between 1950 and 1970, and a steady, though not as dramatic, decline in real prices from 1970 to 1990. Throughout this period, per capita consumption rose. What explains this pattern of prices and quantities?

Figure 2.14 illustrates what was happening. From 1950 to 1990, the demand curve for broilers shifted rightward. A combination of factors drove this rightward shift. In the early 1950s, when chicken was still a luxury meat, increases in consumer income drove the increase in chicken demand. Increased incomes continued to drive chicken demand beyond the 1950s as increasingly affluent consumers stepped up their purchases of premium chicken parts, such as chicken breasts. More recently, though, changes in consumption preferences have driven the rightward shift in demand for broilers. Many consumers believe that when its skin is removed and the meat is not fried, cooked chicken is healthier than beef and pork. Concerns over the health implications of high-fat diets have led American households to substitute chicken for beef and pork.

We know that an increase in demand, holding the supply curve fixed, should cause the equilibrium price to rise. That broiler prices fell between 1950 and 1990

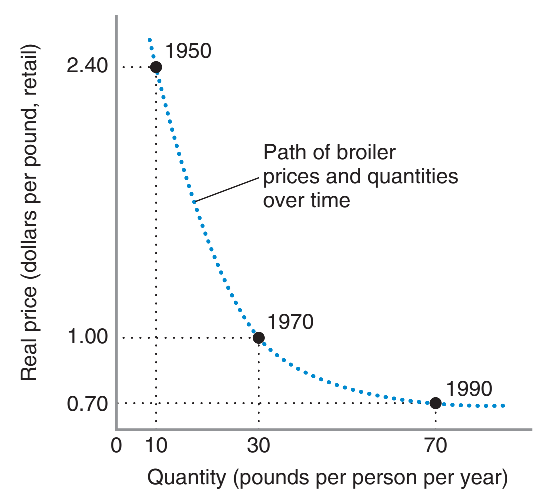


FIGURE 2.13 Prices and Quantities of Chicken Broilers, 1950–1990
In 1950, the price of chicken broilers was $2.40 per pound and annual per capita consumption was about 10 pounds per year. In 1990, the price had fallen to $0.70 per pound and annual per capita consumption had grown to 70 pounds per year.

[8]This example draws from Richard T. Rogers, "Broilers: Differentiating a Commodity," in Larry L. Deutsch (ed.), *Industry Studies* (Englewood Cliffs, NJ: Prentice-Hall, 1993), pp. 3–32. In particular, the information in Figure 2.13 comes from Figure 1 in Rogers' article.

[9]*Per capita quantity* is an average quantity per person. Thus, if the total consumption for chicken broilers is 2 billion pounds per year and the total population is 200 million, the per capita consumption of chicken broilers would be 2,000,000,000/200,000,000 = 10 pounds per year.

[10]A *real price* is a price that is adjusted for the effects of inflation. For example, suppose the price of chicken broilers rose from $1.00 in 1985 to $1.20 in 1995, a 20 percent increase. Suppose, too, that the prices of all goods and services went up by 20 percent on average over this period (i.e., the rate of inflation was 20 percent). Then, we would say that the real price of chicken broilers remained constant because the increase in the actual price of broilers matched the rate of inflation. When broiler prices increase by less than the rate of inflation, we say that real broiler prices have gone down. If broiler prices increase by more than the rate of inflation, we say that real broiler prices have gone up.

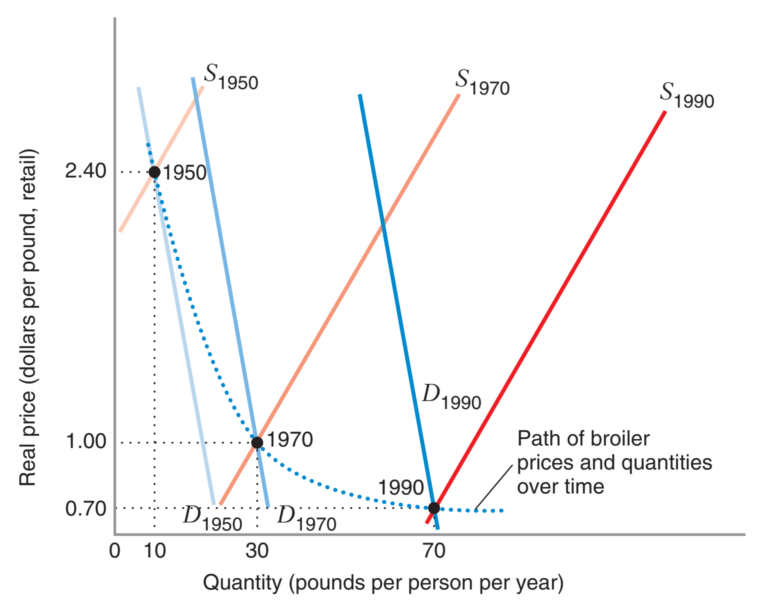


FIGURE 2.14 Supply and Demand for Broilers, 1950–1990
The pattern of prices and quantities in Figure 2.13 can be explained by rightward shifts over time in both the demand and supply curves for broilers. The supply curve shifted from S_{1950} to S_{1970} to S_{1990}, while the demand curve shifted from D_{1950} to D_{1970} to D_{1990}.

indicates that something other than the demand curve must have shifted. Figure 2.14 shows that the pattern of observed broiler prices and quantities is consistent with a simultaneous rightward shift of both the demand and the supply curves. What caused the increase in supply for broilers? In part, the rightward shift in the supply curve is due to technological advances that allow modern firms to producer leaner, higher-quality chickens at a lower cost than small family farms were able to. It is also due to an increase in the number of broiler producers. For example, in 1947, 330 U.S. companies processed broilers for sale to final consumers. Just seven years later that number had more than tripled. The combined effect of technological advances and new entry pushed the supply curve for broilers rightward by an amount that equaled or exceeded the rightward shift in demand. The result is the long-term path for prices and quantities represented by the dashed line in Figures 2.13 and 2.14.

corn can be attributed to both a decrease in demand (e.g., due to the effects of a global currency crisis and China's move toward agricultural self-sufficiency) and an increase in supply (due to an improvement in harvests resulting from the good weather in 1996–1998). The combined effect of both shifts was to decrease the equilibrium price. By contrast, the effect on the equilibrium quantity is more complicated. The decrease in demand tends to push the equilibrium quantity downward, while the increase in supply tends to push the equilibrium quantity upward. Figure 2.12 shows a net increase in equilibrium quantity from 1.5 billion bushels per year to 1.6 billion bushels per year.

2.2 PRICE ELASTICITY OF DEMAND

The **price elasticity of demand** measures the sensitivity of the quantity demanded to price. The price elasticity of demand (denoted by $\epsilon_{Q,P}$) is the percentage change in quantity demanded (Q) brought about by a 1 percent change in price (P), which means that

$$\epsilon_{Q,P} = \frac{\text{percentage change in quantity}}{\text{percentage change in price}}$$

If ΔQ is the change in quantity and ΔP is the change in price, then

$$\text{percentage change in quantity} = \frac{\Delta Q}{Q} \times 100\%$$

and

$$\text{percentage change in price} = \frac{\Delta P}{P} \times 100\%$$

Thus, the price elasticity of demand is

$$\epsilon_{Q,P} = \frac{\frac{\Delta Q}{Q} \times 100\%}{\frac{\Delta P}{P} \times 100\%}$$

or

$$\epsilon_{Q,P} = \frac{\Delta Q}{\Delta P}\frac{P}{Q} \tag{2.3}$$

For example, suppose that when the price of a good is \$10 ($P = 10$), the quantity demanded is 50 units ($Q = 50$), and that when the price increases to \$12 ($\Delta P = 2$), the quantity demanded decreases to 45 units ($\Delta Q = -5$). If we plug these numbers into equation (2.3), we find that in this case the price elasticity of demand is

$$\epsilon_{Q,P} = \frac{\Delta Q}{\Delta P}\frac{P}{Q} = \frac{-5}{2}\frac{10}{50} = -0.5$$

As illustrated by this example, the value of $\epsilon_{Q,P}$ must always be negative, reflecting the fact that demand curves slope downward because of the inverse relationship of price and quantity (see page 26): when price increases, quantity decreases, and vice versa. The following table shows how economists classify the possible range of values for $\epsilon_{Q,P}$.

Value of $\epsilon_{Q,P}$	Classification	Meaning
0	***Perfectly inelastic* demand**	Quantity demanded is completely insensitive to price.
between 0 and -1	***Inelastic* demand**	Quantity demanded is relatively insensitive to price.
-1	***Unitary elastic* demand**	Percentage increase in quantity demanded is equal to percentage decrease in price.
between -1 and $-\infty$	***Elastic* demand**	Quantity demanded is relatively sensitive to price.
$-\infty$	***Perfectly elastic* demand**	Any increase in price results in quantity demanded decreasing to zero, and any decrease in price results in quantity demanded increasing to infinity.

To see the relationship between the price elasticity of demand and the shape of the demand curve, consider Figure 2.15. In this figure, demand curves D_1 and D_2 cross at point A, where the price is P and the quantity is Q. (For the moment ignore the demand curve D_3.) For a given percentage increase in price $\Delta P/P$ from point A, the percentage decrease in quantity demanded, $\Delta Q_2/Q$, along D_2 is larger than the percentage decrease in the quantity demanded, $\Delta Q_1/Q$, along demand curve D_1. Thus, at point A, demand is more elastic on demand curve D_2 than on demand curve

price elasticity of demand A measure of the rate of percentage change of quantity demanded with respect to price, holding all other determinants of demand constant.

perfectly inelastic demand Price elasticity of demand equal to 0.

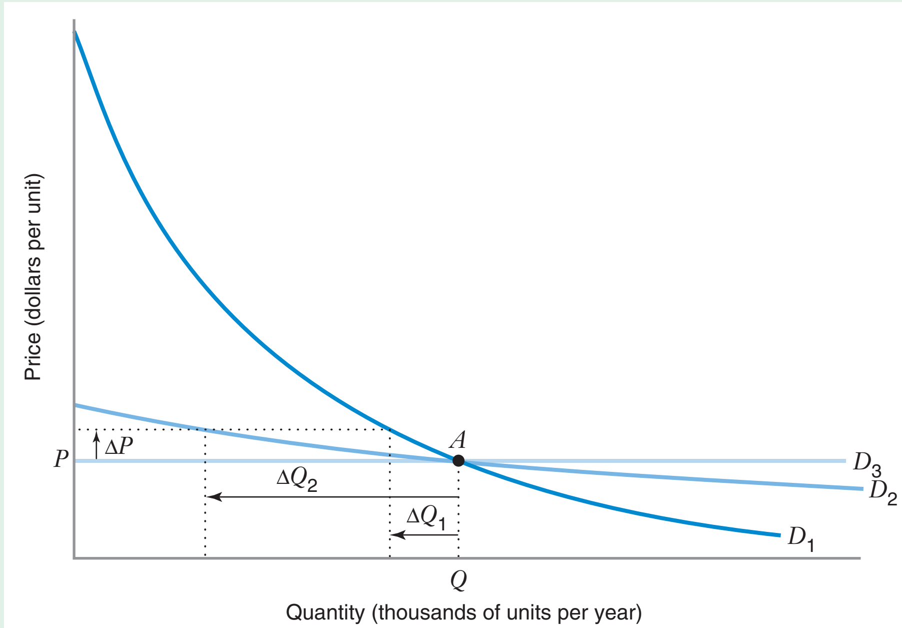
inelastic demand Price elasticity of demand between 0 and -1.

unitary elastic demand Price elasticity of demand equal to -1.

elastic demand Price elasticity of demand between -1 and $-\infty$.

perfectly elastic demand Price elasticity of demand equal to $-\infty$.

FIGURE 2.15 Comparing the Price Elasticity of Demand on Different Demand Curves
If we start at point A, a given percentage increase in price, $\Delta P/P$, along demand curve D_1 results in a relatively small percentage drop in quantity demanded, $\Delta Q_1/Q$, while the same percentage change in price results in a relatively large percentage drop in quantity demanded, $\Delta Q_2/Q$, along demand curve D_2. Thus, at point A, demand is more elastic on demand curve D_2 than on demand curve D_1. The demand curve D_3 is perfectly elastic. Along this demand curve, the price elasticity of demand is equal to minus infinity.



D_1—that is, at point A, the price elasticity of demand is more negative for D_2 than for D_1. This shows that for any two demand curves that cross at a particular point, the flatter of the two curves is more elastic at the point where they cross.

The demand curve D_3 in Figure 2.15 shows what happens in the extreme as demand becomes increasingly elastic. The demand curve D_3 illustrates perfectly elastic demand (i.e., $\epsilon_{Q,P} = -\infty$). Along the perfectly elastic demand curve D_3, any positive quantity can be sold at the price P, so the demand curve is a horizontal line. The opposite of perfectly elastic demand is perfectly inelastic demand (i.e., $\epsilon_{Q,P} = 0$), when the quantity demanded is completely insensitive to price.[11]

The price elasticity of demand can be an extremely useful piece of information for business firms, nonprofit institutions, and other organizations that are deciding how to price their products or services. It is also an important determinant of the structure and nature of competition within particular industries. Finally, the price elasticity of demand is important in determining the effect of various kinds of governmental interventions, such as price ceilings, tariffs, and import quotas. In later chapters, we explore the analysis of these questions using price elasticities of demand.

LEARNING-BY-DOING EXERCISE 2.5

Price Elasticity of Demand

Suppose price is initially \$5, and the corresponding quantity demanded is 1000 units. Suppose, too, that if the price rises to \$5.75, the quantity demanded will fall to 800 units.

[11]In Problem 2.8 at the end of the chapter, you will be asked to sketch the graph of a demand curve that is perfectly inelastic.

Problem What is the price elasticity of demand over this region of the demand curve? Is demand elastic or inelastic?

Solution In this case, $\Delta P = 5.75 - 5 = \$0.75$, and $\Delta Q = 800 - 1000 = -200$, so

$$\epsilon_{Q,P} = \frac{\Delta Q}{\Delta P}\frac{P}{Q} = -\frac{200}{\$0.75}\frac{\$5}{1000} = -1.33$$

Thus, over the range of prices between \$5.00 and \$5.75, quantity demanded falls at a rate of 1.33 percent for every 1 percent increase in price. Because the price elasticity of demand is between -1 and $-\infty$, demand is elastic over this price range (i.e., quantity demanded is relatively sensitive to price).

ELASTICITIES ALONG SPECIFIC DEMAND CURVES

Linear Demand Curves

A commonly used form of the demand curve is the **linear demand curve**, represented by the equation $Q = a - bP$, where a and b are positive constants. In this equation, the constant a embodies the effects of all the factors (e.g., income, prices of other goods) other than price that affect demand for the good. The coefficient b, which is the slope of the demand curve, reflects how the price of the good affects the quantity demanded.[12]

linear demand curve A demand curve in the form $Q = a - bP$.

Any downward-sloping demand curve has a corresponding **inverse demand curve** that expresses price as a function of quantity. We can find the inverse demand curve by taking the equation for the demand curve and solving it for P in terms of Q. The inverse demand curve for the linear demand curve is given by

inverse demand curve An equation for the demand curve that expresses price as a function of quantity.

$$P = \frac{a}{b} - \frac{1}{b}Q$$

The term a/b is called the **choke price**. This is the price at which the quantity demanded falls to 0.[13]

choke price The price at which quantity demanded falls to 0.

Using Equation (2.3), we see that the price elasticity of demand for the linear demand curve in Figure 2.16 is given by the formula

$$\epsilon_{Q,P} = \frac{\Delta Q}{\Delta P}\frac{P}{Q} = -b\frac{P}{Q} \qquad (2.4)$$

This formula tells us that for a linear demand curve, the price elasticity of demand varies as we move along the curve. Between the choke price a/b (where $Q = 0$) and a price of $a/2b$ at the midpoint M of the demand curve, the price elasticity of demand is

[12] However, as you will see soon, the term $-b$ is not the price elasticity of demand.

[13] You can verify that quantity demanded falls to 0 at the choke price by substituting $P = a/b$ into the equation of the demand curve:

$$\begin{aligned} Q &= a - b\left(\frac{a}{b}\right) \\ &= a - a \\ &= 0 \end{aligned}$$

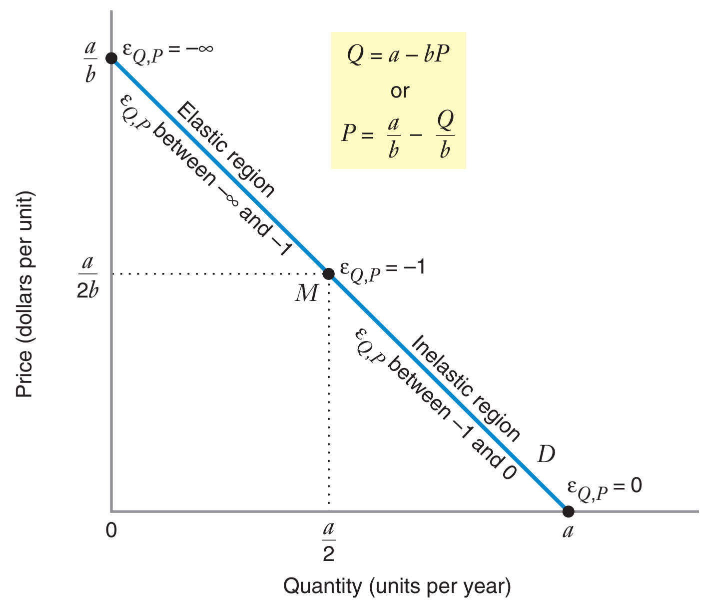


FIGURE 2.16 Price Elasticity of Demand along a Linear Demand Curve
In the region to the northwest of the midpoint *M*, demand is elastic, with the price elasticity of demand between minus infinity and −1. In the region to the southeast of the midpoint *M*, demand is inelastic, with the price elasticity of demand between −1 and 0.

between $-\infty$ and -1. This is known as the elastic region of the demand curve. For prices between $a/2b$ and 0, the price elasticity of demand is between -1 and 0. This is the inelastic region of the demand curve.

Equation (2.4) highlights the difference between the slope of the demand curve, $-b$, and the price elasticity of demand, $-b(P/Q)$. The slope measures the *absolute change* in quantity demanded (in units of quantity) brought about by a *one unit change* in price. By contrast, the price elasticity of demand measures the *percentage change* in quantity demanded brought about by a *1 percent change* in price.

You might wonder why we do not simply use the slope to measure the sensitivity of quantity to price. The problem is that the slope of a demand curve depends on the units used to measure price and quantity. Thus, comparisons of slope across different goods (whose quantity units would differ) or across different countries (where prices are measured in different currency units) would not be very meaningful. By contrast, the price elasticity of demand expresses changes in prices and quantities in common terms (i.e., percentages). This allows us to compare the sensitivity of quantity demanded to price across different goods or different countries.

Constant Elasticity Demand Curves

constant elasticity demand curve A demand curve of the form $Q = aP^{-b}$ where a and b are positive constants. The term b is the price elasticity of demand along this curve.

Another commonly used demand curve is the **constant elasticity demand curve**, given by the general formula: $Q = aP^{-b}$, where a and b are positive constants. For the constant elasticity demand curve, the price elasticity is always equal to the exponent $-b$.[14] For this reason, economists frequently use the constant elasticity demand curve to estimate price elasticities of demand using statistical techniques.

[14] We prove this result in the appendix to this chapter.

LEARNING-BY-DOING EXERCISE 2.6

Elasticities along Special Demand Curves

Problem

(a) Suppose a constant elasticity demand curve is given by the formula $Q = 200P^{-\frac{1}{2}}$. What is the price elasticity of demand?

(b) Suppose a linear demand curve is given by the formula $Q = 400 - 10P$. What is the price elasticity of demand at $P = 30$? At $P = 10$?

Solution

(a) Since this is a constant elasticity demand curve, the price elasticity of demand is equal to $-1/2$ everywhere along the demand curve.

(b) For this linear demand curve, we can find the price elasticity of demand by using equation (2.4): $\epsilon_{Q,P} = (-b)(P/Q)$. Since $b = -10$ and $Q = 400 - 10P$, when $P = 30$,

$$\epsilon_{Q,P} = -10\left(\frac{30}{400 - 10(30)}\right) = -3$$

and when $P = 10$,

$$\epsilon_{Q,P} = -10\left(\frac{10}{400 - 10(10)}\right) = -0.33$$

Note that demand is elastic at $P = 30$, but it is inelastic at $P = 10$ (in other words, $P = 30$ is in the elastic region of the demand curve, while $P = 10$ is in the inelastic region).

Similar Problem: 2.9

PRICE ELASTICITY OF DEMAND AND TOTAL REVENUE

Businesses, management consultants, and government bodies use price elasticities of demand a lot. To see why a business might care about the price elasticity of demand, let's consider how an increase in price might affect a business's **total revenue**, that is, the selling price times the quantity of product it sells, or PQ. You might think that when the price rises, so will the total revenue, but a higher price will generally reduce the quantity demanded. Thus, the "benefit" of the higher price is offset by the "cost" due to the reduction in quantity, and businesses must generally consider this trade-off when they think about raising a price. If the demand is elastic (the quantity demanded is relatively sensitive to price), the quantity reduction will outweigh the benefit of the higher price, and total revenue will fall. If the demand is inelastic (the quantity demanded is relatively insensitive to price), the quantity reduction will not be too severe, and total revenue will go up. Thus, knowledge of the price elasticity of demand can help a business predict the revenue impact of a price increase.

total revenue Selling price times the quantity of product sold.

DETERMINANTS OF THE PRICE ELASTICITY OF DEMAND

Price elasticities of demand have been estimated for many products using statistical techniques. Table 2.1 presents these estimates for a variety of food, liquor, and tobacco

TABLE 2.1 Estimates of the Price Elasticity of Demand for Selected Food, Tobacco, and Liquor Products*

Product	Estimated $\epsilon_{Q,P}$
Cigars	−0.756
Canned and cured seafood	−0.736
Fresh and frozen fish	−0.695
Cheese	−0.595
Ice cream	−0.349
Beer and malt beverages	−0.283
Bread and bakery products	−0.220
Wine and brandy	−0.198
Cookies and crackers	−0.188
Roasted coffee	−0.120
Cigarettes	−0.107
Chewing tobacco	−0.105
Pet food	−0.061
Breakfast cereal	−0.031

**Source:* Emilio Pagoulatos, and Robert Sorensen, "What Determines the Elasticity of Industry Demand," *International Journal of Industrial Organization*, 4 (1986): 237–250.

products in the United States, while Table 2.2 presents estimates for various modes of transportation. What determines these elasticities? Consider the estimated elasticity of −0.107 for cigarettes in Table 2.1, which indicates that a 10 percent increase in the price of cigarettes would result in a 1.07 percent drop in the quantity of cigarettes demanded. This tells us that cigarettes have an inelastic demand: When the prices of all the individual brands of cigarettes go up (perhaps because of an increase in cigarette taxes), overall consumption of cigarettes is not likely to be affected very much. This conclusion makes sense. Even though consumers might want to cut back their consumption when cigarettes become more expensive, most would find it difficult to do so because cigarettes are habit forming.

In many circumstances, decision makers do not have precise numerical estimates of price elasticities of demand based on statistical techniques. Consequently, they have

TABLE 2.2 Estimates of the Price Elasticity of Demand for Selected Modes of Transportation*

Category	Estimated $\epsilon_{Q,P}$
Airline travel, leisure	−1.52
Rail travel, leisure	−1.40
Airline travel, business	−1.15
Rail travel, business	−0.70
Urban transit	between −0.04 and −0.34

**Source:* Elasticities from the cross-sectional studies summarized in Tables 2, 3, 4 in Tae Hoon Oum, W. G. Waters II, and Jong-Say Yong, "Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates," *Journal of Transport Economics and Policy* (May 1992): 139–154.

to rely on their knowledge of the product and the nature of the market to make educated conjectures about price sensitivity.

Here are some factors that determine a product's price elasticity of demand—that is, the extent to which demand is relatively sensitive or insensitive to price.

- *Demand tends to be more price elastic when there are good substitutes for a product* (or, alternatively, demand tends to be less price elastic when the product has few or not very satisfactory substitutes). One reason that the demand for airline travel by leisure travelers is price elastic (as Table 2.2 shows) is that leisure travelers usually perceive themselves as having reasonably good alternatives to traveling by air; for example, they can often travel by automobile instead. For business travelers, automobile travel is usually a less desirable substitute because of the time-sensitive nature of much business travel. This explains why, as Table 2.2 shows, the price elasticity of demand for business travel is smaller (in absolute magnitude) than that for leisure travel.
- *Demand tends to be more price elastic when a consumer's expenditure on the product is large (either in dollar terms or as a fraction of total expenditures).* For example, demand is more elastic for products such as refrigerators or automobiles. By contrast, demand tends to be less price elastic when a consumer's expenditure on the product is small, as is the case for many of the individual grocery items in Table 2.1. When a consumer must spend a lot of money to buy a product, the gain from carefully evaluating the purchase and paying close attention to price is greater than it is when the item does not entail a large outlay of money.
- *Demand tends to be less price elastic when the product is seen by consumers as being a necessity.* For example, household demand for water and electricity tends to be relatively insensitive to price because virtually no household can do without these essential services.

MARKET-LEVEL VERSUS BRAND-LEVEL PRICE ELASTICITIES OF DEMAND

A common mistake in the use of price elasticities of demand is to suppose that just because the demand for a product is inelastic, the demand each seller of that product faces is also inelastic. Consider, for example, cigarettes. As already discussed, the demand for cigarettes is not especially sensitive to price: an increase in the price of all brands of cigarettes would only modestly affect overall cigarette demand. However, if the price of only a single brand of cigarettes (e.g., Salem) went up, the demand for that brand would probably drop substantially because consumers would switch to the now lower-priced brands whose prices did not change. Thus, even if demand is inelastic at the market level, it can be highly elastic at the individual brand level.

The distinction between market-level and brand-level elasticities reflects the impact of substitution possibilities on the degree to which consumers are sensitive to price. In the case of cigarettes, for example, a typical smoker *needs* cigarettes because there are no good alternatives. But that smoker doesn't necessarily *need* Salem cigarettes because, when the price of Salem goes up, switching to another brand will provide more or less the same degree of satisfaction.

What determines whether a firm should use market-level or brand-level elasticity in assessing the effect of a price change? The answer depends on what the firm expects its competitors to do. If a firm expects its rivals to quickly match its price change, then the market-level elasticity will provide the appropriate measure of how the demand for

APPLICATION 2.3

How People Buy Cars: The Importance of Brands

Using modern statistical techniques, Steven Berry, James Levinsohn, and Ariel Pakes estimated price elasticities of demand for numerous makes of automobiles.[15] Table 2.3 shows some of their estimates. These estimates illustrate that demands for individual models of automobiles are highly elastic (between −3.5 and −6.5). By contrast, estimates of the market-level price elasticity of demand for automobiles generally fall between −1 and −1.5.[16] This highlights the distinction between brand-level price elasticity of demand and market-level price elasticity of demand.

Brand-level price elasticities of demand are more negative than market-level price elasticities of demand because consumers have greater substitution possibilities when only one firm raises its price. This suggests that the most negative brand-level elasticities for automobiles should be in those market segments in which consumers have the greatest substitution possibilities. The data in Table 2.3 bear this out. The most elastic demands are generally for automobiles in the compact and subcompact market segments (Mazda 323, Nissan Sentra), which are the most crowded. By contrast, demands for cars in the luxury segment (Lexus LS400, BMW 735i) are somewhat less price elastic because there are fewer substitutes for them.

TABLE 2.3 Estimates of Price Elasticities of Demand for Selected Makes of Automobiles, 1990*

Model	Price	Estimated $\epsilon_{Q,P}$
Mazda 323	\$ 5,039	−6.358
Nissan Sentra	\$ 5,661	−6.528
Ford Escort	\$ 5,663	−6.031
Chevrolet Cavalier	\$ 5,797	−6.433
Honda Accord	\$ 9,292	−4.798
Ford Taurus	\$ 9,671	−4.220
Buick Century	\$ 10,138	−6.755
Nissan Maxima	\$ 13,695	−4.845
Acura Legend	\$ 18,944	−4.134
Lincoln Town Car	\$ 21,412	−4.320
Cadillac Seville	\$24,544	−3.973
Lexus LS400	\$27,544	−3.085
BMW 735i	\$37,490	−3.515

**Source:* Table V in S. Berry, J. Levinsohn, and A. Pakes, "Automobile Prices in Market Equilibrium," *Econometrica* 63 (July 1995): 841–890.

the firm's product is likely to change with price. If, by contrast, a firm expects its rivals not to match its price change (or to do so only after a long time lag), then the brand-level elasticity is appropriate.

2.3 OTHER ELASTICITIES

We can use elasticity to characterize the responsiveness of demand to any of the determinants of demand. Two of the more common elasticities in addition to the price elasticity of demand are the income elasticity of demand and the cross-price elasticity of demand.

INCOME ELASTICITY OF DEMAND

income elasticity of demand The ratio of the percentage change of quantity demanded to the percentage change of income, holding price and all other determinants of demand constant.

The **income elasticity of demand** is the ratio of the percentage change of quantity demanded to the percentage change of income, holding price and all other determinants

[15] S. Berry, J. Levinsohn, and A. Pakes, "Automobile Prices in Market Equilibrium," *Econometrica*, 63 (July 1995): 841–890.

[16] See, for example, S. H. Hymans, "Consumer Durable Spending: Explanation and Prediction," *Brookings Papers on Economic Activity*, 2 (1970): 173–199.

TABLE 2.4 Estimates of the Income Elasticity of Demand for Selected Food Products*

Product	Estimated $\epsilon_{Q,I}$
Cream	1.72
Peaches	1.43
Apples	1.32
Fresh peas	1.05
Oranges	0.83
Onions	0.58
Eggs	0.44
Milk	0.50
Butter	0.37
Potatoes	0.15
Margarine	−0.20
Flour	−0.36

**Sources:* The first 10 entries in Table 2.4 come from Table 1-1 in Daniel B. Suits, "Agriculture," Chapter 1 in *The Structure of American Industry*, 9th edition, Walter Adams and James Brock, eds. (Englewood Cliffs, NJ: Prentice-Hall), 1995; the last two entries come from H. S. Houthhakker and Lester D. Taylor, *Consumer Demand in the United States,* 1929–1970 (Cambridge, MA: Harvard University Press), 1966.

of demand constant:

$$\epsilon_{Q,I} = \frac{\frac{\Delta Q}{Q} \times 100\%}{\frac{\Delta I}{I} \times 100\%}$$

or, after rearranging terms,

$$\epsilon_{Q,I} = \frac{\Delta Q}{\Delta I}\frac{I}{Q} \tag{2.5}$$

Table 2.4 shows estimated income elasticities of demand for a number of different food products. As the table shows, an income elasticity can be positive or negative. A positive income elasticity (e.g., apples, oranges, butter) indicates that demand for a good rises as consumer income goes up; a negative income elasticity (e.g., margarine, flour) indicates that demand for a good falls as consumer income goes up.

CROSS-PRICE ELASTICITY OF DEMAND

The **cross-price elasticity of demand** for good i with respect to the price of good j is the ratio of the percentage change of the quantity of good i demanded to the percentage change of the price of good j:

cross-price elasticity of demand The ratio of the percentage change of the quantity of one good demanded with respect to the percentage change in the price of another good.

$$\epsilon_{Q_i,P_j} = \frac{\frac{\Delta Q_i}{Q_i} \times 100\%}{\frac{\Delta P_j}{P_j} \times 100\%}$$

TABLE 2.5 Cross-Price Elasticities of Demand for Selected Meat Products*

	Price of Beef	Price of Pork	Price of Chicken
Demand for Beef	−0.65**	0.01***	0.20
Demand for Pork	0.25	−0.45	0.16
Demand for Chicken	0.12	0.20	−0.65

**Sources:* Table 1-4 in Daniel B. Suits, "Agriculture," Chapter 1 in *The Structure of American Industry*, 8th edition, Walter Adams and James Brock, eds. (Englewood Cliffs, NJ: Prentice-Hall, 1990).

**This is the price elasticity of demand for beef.

***This is the cross-price elasticity of demand for beef with respect to the price of pork.

or, after rearranging terms,

$$\epsilon_{Q_i,P_j} = \frac{\Delta Q_i}{\Delta P_j}\frac{P_j}{Q_i} \tag{2.6}$$

where P_j denotes the initial price of good j, and Q_i denotes the initial quantity of good i demanded. Table 2.5 shows cross-price elasticities of demand for selected meat products.

APPLICATION 2.4

How People Buy Cars: The Importance of Price

Table 2.6 presents estimates of the cross-price elasticities of demand for some of the makes of automobiles shown in Table 2.3. (The table contains the price elasticities of demand for these makes as well.) The table shows, for example, that the cross-price elasticity of demand for Ford Escort with respect to the price of a Nissan Sentra is 0.054, indicating that the demand for Ford Escorts goes up at a rate of 0.054 percent for each 1 percent increase in the price of a Nissan Sentra. Although all of the cross-price elasticities are fairly small, note that the cross-price elasticities between compact cars (Sentra, Escort) and luxury cars (Lexus LS400, BMW 735i) are zero or close to zero. This makes sense: Compacts and luxury cars are distinct market segments. Different people buy BMWs than buy Ford Escorts, so the demand for one should not be much affected by the price of the other. By contrast, the cross-price elasticities within the compact segment are relatively higher. This suggests that consumers within this segment view Sentras and Escorts as substitutes for one another.

TABLE 2.6 Cross-Price Elasticities of Demand for Selected Makes of Automobiles*

	Price of Sentra	Price of Escort	Price of LS400	Price of 735i
Demand for Sentra	−6.528**	0.078***	0.000	0.000
Demand for Escort	0.054	−6.031	0.001	0.000
Demand for LS400	0.000	0.001	−3.085	0.093
Demand for 735i	0.000	0.001	0.032	−3.515

**Sources:* Adapted from Table VI in S. Berry, J. Levinsohn, and A. Pakes, "Automobile Prices in Market Equilibrium," *Econometrica* 63 (July 1995): 841–890.

**This is the price elasticity of demand for a Sentra.

***This is the cross-price elasticity of demand for a Sentra with respect to the price of an Escort.

APPLICATION 2.5

Coke versus Pepsi[17]

If the price of Coke goes down, what is the effect on the demand for Pepsi? And if Pepsi's price goes down, how is Coke's demand affected? Farid Gasmi, Quang Vuong, and Jean-Jacques Laffont (GVL) studied competitive interactions in the U.S. soft drink market and estimated demand equations for Coca-Cola and Pepsi.[18] Using the average values of prices and other variables in their study, we can infer the price elasticity, cross-price elasticity, and income elasticities of demand for Coke and Pepsi shown in Table 2.7.[19]

As you can see in Table 2.7, the cross-price elasticities of demand are positive numbers (0.52 and 0.64). This tells us that a decrease in Coke's price will decrease the demand for Pepsi, and a decrease in Pepsi's price will decrease the demand for Coke. Thus, consumers view these products as substitutes, and a decrease in the price of one brand would hurt demand for the other. In addition, the demand for both products goes up when consumer income goes up, indicating that increases in consumer incomes benefit both brands. Finally, the price elasticity of demand for each brand falls in the range between −1 and −∞. Thus, the brand-level demand for both Coke and Pepsi is elastic.

TABLE 2.7 Price, Cross-Price, and Income Elasticities of Demand for Coca-Cola and Pepsi

Elasticity	Coca-Cola	Pepsi
Price elasticity of demand	−1.47	−1.55
Cross-price elasticity of demand	0.52	0.64
Income elasticity of demand	0.58	1.38

Cross-price elasticities can be positive or negative. If $\epsilon_{Q_i,P_j} > 0$, a higher price for good j increases the demand for good i. In this case, goods i and j are **demand substitutes**. Table 2.5 shows examples of demand substitutes. For example, the fact that the cross-price elasticity of demand for chicken with respect to the price of beef is positive (0.12) indicates that as the price of beef goes up, the quantity of chicken demanded goes up. Evidently, as beef becomes more expensive, consumers purchase more chicken.

demand substitutes Two goods related in such a way that if the price of one increases, demand for the other increases.

By contrast, if $\epsilon_{Q_i,P_j} < 0$, a higher price of good j decreases the demand for good i. This relationship indicates that goods i and j are **demand complements**. Breakfast cereal and milk are examples of demand complements. As the price of breakfast cereal goes up, consumers will buy less cereal and will thus need less milk to pour on top of their cereal. Consequently, the demand for milk will fall.

demand complements Two goods related in such a way that if the price of one increases, demand for the other decreases.

PRICE ELASTICITY OF SUPPLY

price elasticity of supply The percentage change in quantity supplied for each percent change in price, holding all other determinants of supply constant.

The **price elasticity of supply** measures the sensitivity of quantity supplied Q^s to price. The price elasticity of supply—denoted by $\epsilon_{Q^s,P}$—tells us the percentage change

[17]This example is based on F. Gasmi, J. J. Laffont, and Q. Vuong, "Econometric Analysis of Collusive Behavior in a Soft Drink Market," *Journal of Economics and Management Strategy*, 1 (summer 1992): 278–311. It was inspired by the classroom notes of our former colleague Matthew Jackson.

[18]In Chapter 13, we will use these demand functions to study price competition between Coke and Pepsi.

[19]GVL estimated these demand functions under several different assumptions about market behavior. The ones reported here correspond to what the authors believe is the best model.

in quantity supplied for each percent change in price:

$$\epsilon_{Q^s,P} = \frac{\frac{\Delta Q^s}{Q^s} \times 100\%}{\frac{\Delta P}{P} \times 100\%}$$

$$= \frac{\Delta Q^s}{\Delta P}\frac{P}{Q^s}$$

This formula applies to both the firm level and the market level. The firm-level price elasticity of supply tells us the sensitivity of an individual firm's supply to price, while the market-level price elasticity of supply tells us the sensitivity of market supply to price.

2.4 ELASTICITY IN THE LONG RUN VERSUS THE SHORT RUN

long-run demand curve The demand curve that pertains to the period of time in which consumers can fully adjust their purchase decisions to changes in price.

short-run demand curve The demand curve that pertains to the period of time in which consumers cannot fully adjust their purchase decisions to changes in price.

long-run supply curve The supply curve that pertains to the period of time in which producers can fully adjust their supply decisions to changes in price.

short-run supply curve The supply curve that pertains to the period of time in which sellers cannot fully adjust their supply decisions in response to changes in price.

GREATER ELASTICITY IN THE LONG RUN THAN IN THE SHORT RUN

Consumers cannot always adjust their purchasing decisions instantly in response to a change in price. For example, a consumer faced with an increase in the price of natural gas can, in the short run, turn down the thermostat, which will reduce consumption. But over time, this consumer can reduce natural gas consumption even more by replacing the old furnace with an energy-efficient model. Thus, it is useful to distinguish between the **long-run demand curve** for a product—the demand curve that pertains to the period of time in which consumers can *fully* adjust their purchase decisions to changes in price—and the **short-run demand curve**—the demand curve that pertains to the period of time in which consumers cannot fully adjust their purchasing decisions to changes in price. We would expect that for products, such as natural gas, for which consumption is tied to physical assets whose stocks change slowly, long-run demand would be more price elastic than short-run demand. Figure 2.17 illustrates this possibility. The long-run demand curve is "flatter" than the short-run demand curve.

Similarly, firms sometimes cannot fully adjust their supply decisions in response to changes in price. For example, in the short run, a producer of semiconductors might not be able to increase its supply of chips in response to an increase in price by very much because it faces a capacity constraint—a facility can only produce so many chips, even if extra workers are hired. However, if the price increase is expected to be permanent, then the firm can expand the capacity of its existing facilities or build new ones. The increase in the quantity supplied as a result of the price increase will thus be greater in the long run than in the short run. Figure 2.18 illustrates the distinction between the **long-run supply curve**—the supply curve that pertains to the period of time in which sellers can fully adjust their supply decisions in response to changes in price, and the **short-run supply curve**—the supply curve that pertains to the period of time in which sellers cannot fully adjust their supply decisions in response to a change in price. Figure 2.18 shows that for a good such as semiconductors the long-run supply curve is flatter than the short-run supply curve.

GREATER ELASTICITY IN THE SHORT RUN THAN IN THE LONG RUN

For certain goods, long-run market demand can be *less elastic* than short-run demand. This is particularly likely to be true for goods such as automobiles or

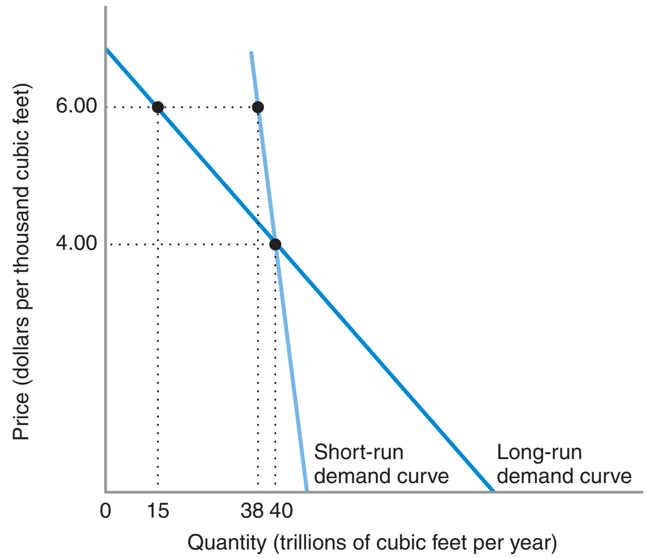


FIGURE 2.17 Short-Run and Long-Run Demand Curves for Natural Gas
In the short run, an increase in the price of natural gas from \$4 to \$6 (per thousand cubic feet) induces consumers to reduce their quantity demanded from a rate of 40 trillion cubic feet per year to 38 trillion cubic feet per year. In the long run, though, when consumers can fully adjust to the price increase from \$4 to \$6, the quantity demanded falls to a rate of 15 trillion cubic feet per year.

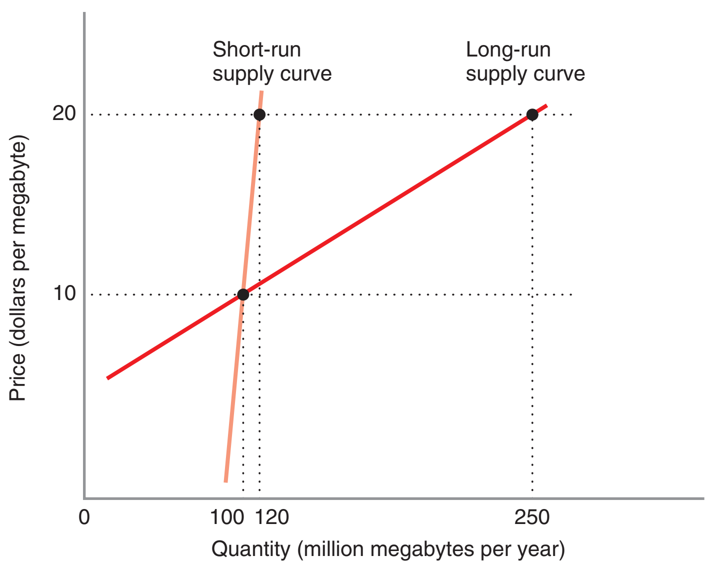


FIGURE 2.18 Short-Run and Long-Run Supply Curves for Semiconductors
In the short run, an increase in the price of semiconductors from \$10 to \$20 per megabyte induces a small increase in the quantity supplied (from 100 million to 120 million megabytes of chips per year). In the long run, though, when producers can fully adjust to the price increase, the long-run supply curve applies and the quantity supplied rises to a rate of 250 million megabytes of chips per year.

APPLICATION 2.6

Crude Oil: Price and Demand

Using data on oil prices and oil consumption over the years 1970 through 2000, John C. B. Cooper estimated short-run and long-run price elasticities of demand for crude oil for 23 different countries.[20] Table 2.8 shows estimates for some of the countries he studied. For example, the short-run price elasticity of demand for oil in Japan was estimated to be −0.071, while the long-run price elasticity of demand was estimated to be −0.357.

For all countries, demand in the short run is highly price inelastic. Even though demand in the long run is also price inelastic, it is less so than in the short run. This is consistent with the idea that, in the long run, buyers of oil make adjustments to their consumption in response to higher or lower prices but do not make such adjustments in the short run.

TABLE 2.8 Long-Run and Short-Run Price Elasticities of Demand for Crude Oil in Selected Countries

	Price Elasticity	
Country	**Short-Run**	**Long-Run**
Australia	−0.034	−0.068
France	−0.069	−0.568
Germany	−0.024	−0.279
Japan	−0.071	−0.357
Korea	−0.094	−0.178
Netherlands	−0.057	−0.244
Spain	−0.087	−0.146
United Kingdom	−0.068	−0.182
United States	−0.061	−0.453

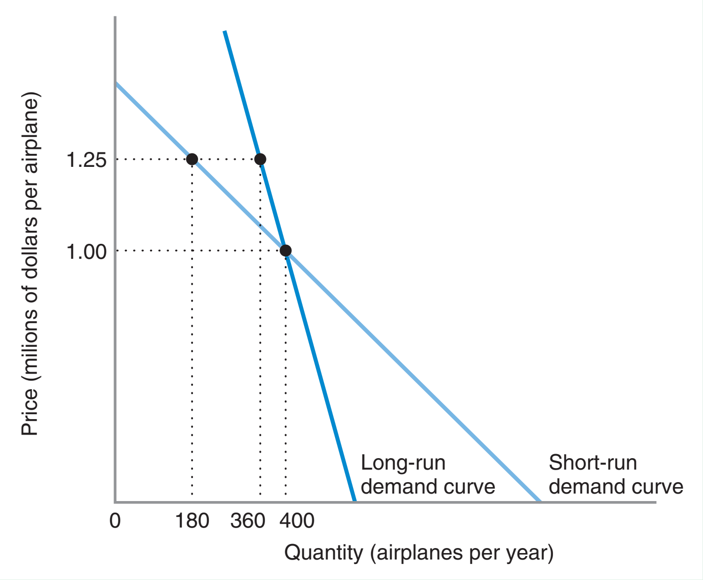


FIGURE 2.19 Short-Run and Long-Run Demand Curves for Commercial Aircraft
An increase in the price of a commercial aircraft from $1 million to $1.25 million per airplane is likely to reduce the long-run rate of demand only modestly, from 400 to 360 aircraft per year, as illustrated by the long-run demand curve. However, in the short run (e.g., the first year after the price increase), the rate of demand will fall more dramatically, from 400 aircraft per year to just 180 aircraft per year, as shown by the short-run demand curve. Eventually, though, as existing aircraft wear out, the rate of demand will rise to the long-run level (360 aircraft per year), corresponding to the new price of $1.25 million per airplane.

durable goods Goods, such as automobiles or airplanes, that provide valuable services over many years.

airplanes—**durable goods**—that provide valuable services over many years. To illustrate this point, consider the demand for commercial airplanes. Suppose that Boeing and Airbus (the world's two producers of commercial aircraft) are able to raise the prices of new commercial aircraft. It seems unlikely that this would dramatically affect the demand for aircraft in the long run: Airlines, such as United and British Airways,

[20] John C. B. Cooper, "Price Elasticity of Demand for Crude Oil: Estimates for 23 Countries," *OPEC Review* (March 2003), pp. 3–8.

APPLICATION 2.7

The DRAM Price Collapse of 1996[21]

DRAM (dynamic random access memory) chips are semiconductor integrated circuits used for memory in personal computers. DRAM chips, produced by such companies, as Samsung, NEC, and Hitachi, are purchased by manufacturers of personal computers, as well as by producers of cell phones, video games, and other digital electronic equipment.

Figure 2.20 shows that between 1993 and 1996, the world market for DRAM chips was stable. Prices held steady at about $30 per megabyte. But in 1996, prices suddenly collapsed. By the end of that year, they had fallen to $5 per megabyte. The collapse in DRAM prices was especially surprising because as late as the summer of 1995, analysts and industry observers were predicting that prices would go up! In fact, many analysts believed that the DRAM market was on the verge of an unprecented rise in prices.

What happened? The price collapse of 1996 came about as a result of several factors that can be depicted using supply and demand analysis. First, most of the major producers believed that the robust growth in demand for personal computers (PCs) from 1992 to 1995 (more than 20 percent a year) would not only continue, but also accelerate. In addition, it was widely believed that the introduction of Windows 95 in August 1995 would spur significant additional demand from PC owners needing memory upgrades. On the basis of these predictions, most producers expected that prices would increase by about $5 per megabyte over the 1995 level, to $35 per megabyte. In light of these expectations, producers moved along the long-run market supply curve LS_{1996}, as shown in Figure 2.21, adding output to the industry by increasing production capacity. If forecasts about demand had been correct, the market equilibrium in 1996 would have occurred at point A.

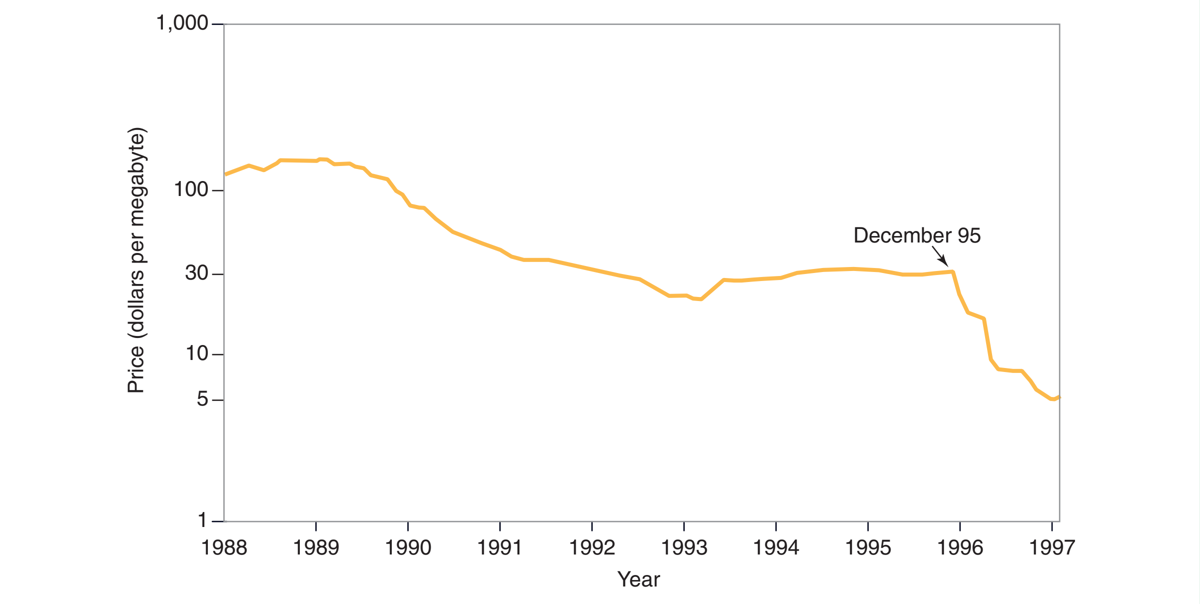


FIGURE 2.20 The Market for DRAM Chips, 1988–1996
In December 1995, the price of DRAM chips was about $30 per megabyte. In 1996 the market collapsed, and prices fell to $5 per megabyte by December 1996.

[21]This example draws from E. Capocchi, B. Firsov, and L. Pachano, "The DRAM Industry," unpublished term paper, Kellogg School of Management (March 1997).

But demand for DRAM chips did not grow. In the United States, PC demand stalled during the Christmas season of 1995, and it stayed flat throughout much of 1996. Moreover, adoption of Windows 95 occurred more slowly than most analysts had anticipated, so the expected flood of memory upgrades did not occur. As a result, computer producers that had stocked up on DRAM chips in the last six months of 1995, in anticipation of possible supply shortages, now had excessive inventories of DRAMs. When customers demanded even fewer chips than they had in 1995, the actual 1996 demand curve (D_{1996}, actual, in Figure 2.21) was well to the left of the expected demand curve (D_{1996}, expected).

By the time new production capacity came on line in early 1996, producers were operating on the short-run market supply curve, shown as SS_{1996} in Figure 2.21. The steep short-run supply curve reflects the willingness of DRAM producers to operate existing fabs even at low DRAM prices. The resulting 1996 equilibrium (point *B* in Figure 2.21) occurred at a price of about \$5 per megabyte, well below the 1995 price of \$30 per megabyte.

Supply and demand analysis would predict that DRAM prices would eventually go up from their 1996 low. Semiconductor output would be reduced by not replacing existing fabs as they wore out, and supply would be more in line with the long-run market supply curve. This is what happened. Many of the major producers reduced output levels, and DRAM prices increased.

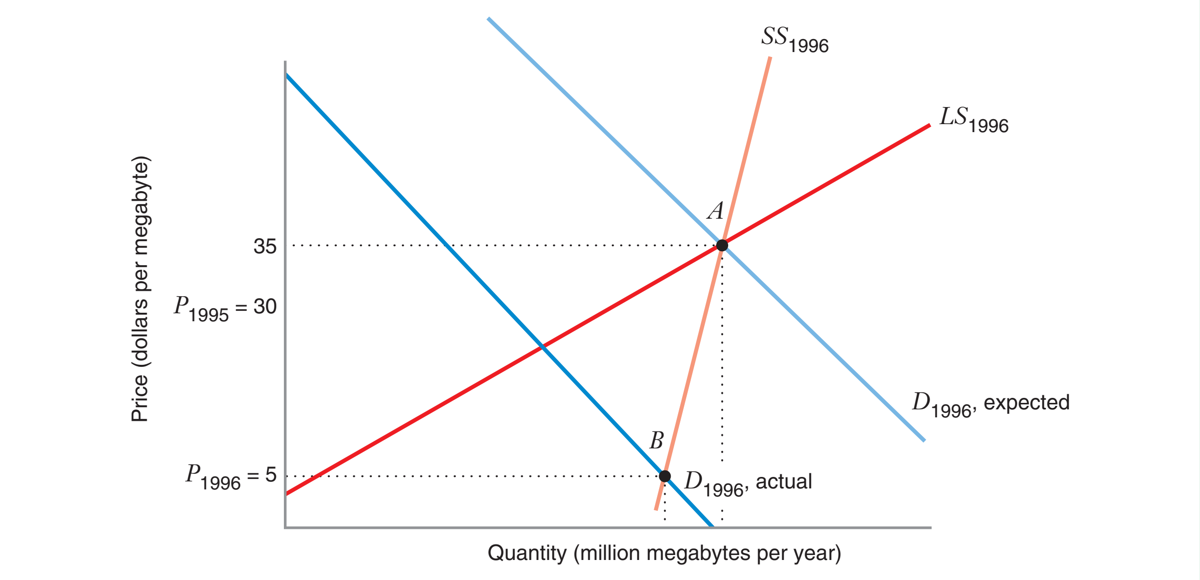


FIGURE 2.21 The Market for DRAM Chips, 1996
DRAM suppliers, anticipating a price of about \$35 per megabyte in 1996, built new production capacity (new fabs) and effectively expanded output along the long-run supply curve, LS_{1996}. Had forecasts of demand been correct, the market equilibrium would have occurred at point *A*. However, once the new capacity was built and prices fell in response to an unanticipated decline in demand in 1996, producers operated along their short-run supply curve, SS_{1996}. By mid-1996, when the DRAM market reached a short-run equilibrium at point *B*, DRAM prices had fallen to \$5 per megabyte.

need aircraft to do their business. There are no feasible substitutes.[22] But in the short run, the impact of higher aircraft prices might be dramatic. Airlines that might have operated an aircraft for 15 years might now try to get an extra 2 or 3 years out of it before replacing it. Thus, while demand for new commercial aircraft in the long run might be relatively price inelastic, in the short run (within 2 or 3 years of the price change), demand would be relatively more elastic. Figure 2.19 shows this possibility. The steeper demand curve corresponds to the long-run effect of the price increase in the total size of aircraft fleets worldwide; the flatter demand curve shows the effect of the price increase on orders for new aircraft in the first year after the price increase.

For some goods, long-run market supply can be less elastic than short-run market supply. This is especially likely to be the case for goods that can be recycled and resold in the secondary market (i.e., the market for used or recycled goods). For example, in the short run an increase in the price of aluminum would elicit an increased supply from two sources: additional new aluminum and recycled aluminum made from scrap. However, in the long run, the stock of scrap aluminum will diminish, and the increase in quantity supplied induced by the increased price will mainly come from the production of new aluminum.

2.5 BACK-OF-THE-ENVELOPE CALCULATIONS

So where do demand curves come from, and how do you derive the equation of a demand function for a real product in a real market? One approach to determining demand curves involves collecting data on the quantity of a good purchased in a market, the prices of that good, and other possible determinants of that good's demand and then applying statistical methods to estimate an equation for the demand function that best fits the data. This broad approach is data-intensive: the analyst has to collect enough data on quantities, prices, and other demand drivers, so that the resulting statistical estimates are sensible. However, analysts often lack the resources to collect enough data for a sophisticated statistical analysis, so they need some techniques that allow them, in a conceptually correct way, to infer the shape or the equation of a demand curve from fragmentary information about prices, quantities, and elasticities. These techniques are called *back-of-the-envelope calculations* because they are simple enough to do on the back of an envelope.

FITTING LINEAR DEMAND CURVES USING QUANTITY, PRICE, AND ELASTICITY INFORMATION

Often, you can obtain information on the prevailing or typical prices and quantities within a particular market as well as estimates of the price elasticity of demand in that market. These estimates might come from statistical studies (this is where the elasticities in Tables 2.1, 2.2, and 2.3 came from) or the judgments of informed observers (e.g., industry participants, investment analysts, consultants). If you assume as a rough approximation that the equation of the demand curve is linear (i.e., $Q = a - bP$), you can then derive the equation of this linear demand (i.e., the values of a and b) from these three pieces of information (prevailing price, prevailing quantity, and estimated elasticity).

The approach to fitting a linear demand curve to quantity, price, and elasticity data proceeds as follows. Suppose Q^* and P^* are the known values of quantity and price

[22]That is not to say there would be no impact on demand. Higher aircraft prices may raise the costs of entering the airline business sufficiently that some prospective operators of airlines would choose to stay out of the business.

in this market, and $\epsilon_{Q,P}$ is the estimated value of the price elasticity of demand. Recall the formula for the price elasticity of demand for a linear demand function.

$$\epsilon_{Q,P} = -b\frac{P^*}{Q^*} \tag{2.7}$$

Solving equation 2.7 for b yields

$$b = -\epsilon_{Q,P}\frac{Q^*}{P^*} \tag{2.8}$$

To solve for the intercept a, we note that Q^* and P^* must be on the demand curve. Thus, it must be that $Q^* = a - bP^*$, or $a = Q^* + bP^*$.

Substituting the expression in equation (2.8) for b gives

$$a = Q^* + \left(-\epsilon_{Q,P}\frac{Q^*}{P^*}\right)P^*$$

Then, by canceling P^* and factoring out Q^*, we get

$$a = (1 - \epsilon_{Q,P})Q^* \tag{2.9}$$

Taken together, equations (2.8) and (2.9) provide a set of formulas for generating the equation of a linear demand curve.

We can illustrate the fitting process with the chicken broiler market discussed in Application 2.2. In 1990, the per capita consumption of chicken in the United States was about 70 pounds per person, while the average inflation-adjusted retail price was about \$0.70 per pound. Demand for broilers is relatively price inelastic, with estimates in the range of −0.5 to −0.6.[23] Thus,

$$Q^* = 70$$
$$P^* = 0.70$$
$$\epsilon_{Q,P} = -0.55 \text{ (splitting the difference)}$$

Applying equations (2.8) and (2.9), we get

$$b = -(-0.55)\frac{70}{0.70} = 55$$

$$a = [1 - (-0.55)]70 = 108.5$$

Thus, the equation of our demand curve for chicken broilers in 1990 is $Q = 108.5 - 55P$.

This curve is depicted in Figure 2.22.

IDENTIFYING SUPPLY AND DEMAND CURVES ON THE BACK OF AN ENVELOPE

Earlier in this chapter, we discussed how exogenous factors can cause shifts in demand and supply that alter the equilibrium prices and quantities in a market. In this section, we show how information about such shifts and observations of the resulting market prices can be used to do back-of-the-envelope derivations of supply and demand curves.

We will use a specific example to illustrate the logic of the analysis. Consider the market for crushed stone in the United States in the late 1990s. Let's suppose that

[23]All data are from Richard T. Rogers (1993), "Broilers: Differentiating a Commodity," in Duetsch, Larry (ed.), *Industry Studies* (Englewood Cliffs, NJ: Prentice-Hall), pp. 3–32. See especially the data summarized on pp. 4–6.

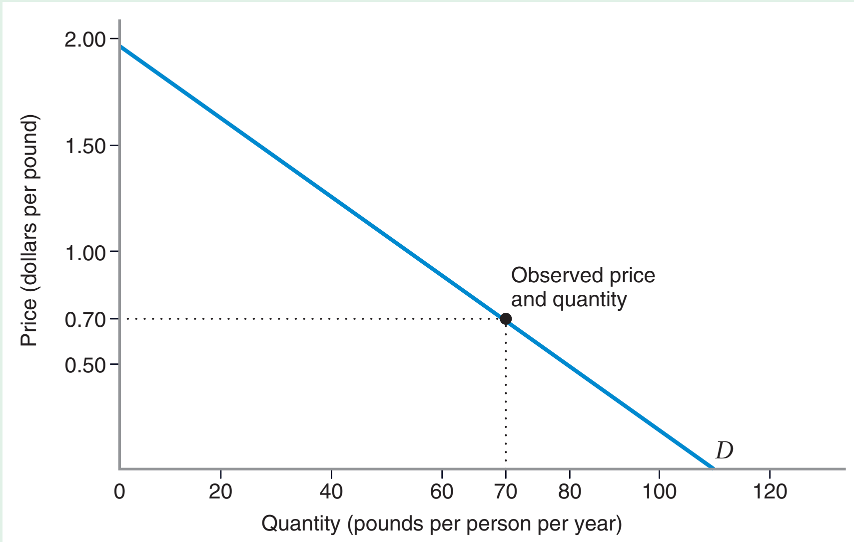


FIGURE 2.22 Fitting a Linear Demand Curve to Observed Market Data
A linear demand curve *D* has been fitted to the observed data in the U.S. market for chicken broilers.

the market demand and supply curves for crushed stone are linear: $Q^d = a - bP$ and $Q^s = f + hP$. Since we expect the demand curve to slope downward and the supply curve to slope upward, we expect that $b > 0$ and $h > 0$.

Now, suppose that we have the following information about the market for crushed stone between 1995 and 1999:

- Between 1995 and 1997, the market was uneventful. The market price was \$9 per ton, and 30 million tons were sold each year.
- In 1998, there was a 1-year burst of highway building. The market price of crushed stone rose to \$10 per ton, and 33 million tons were sold.
- By 1999, the burst of new construction had ended. A new union contract raised the wages of workers in the crushed stone industry. The market price of crushed stone was \$10 per ton, and 28 million tons were sold.

Let's now put this information to work. The 1-year burst of highway building in 1998 most likely resulted in a rightward shift in the demand curve for crushed stone. Let's assume that shift is parallel, as shown in Figure 2.23. On the assumption that there was no reason for any appreciable shift in the supply curve during the period 1995–1998, the rightward shift in demand allows us to compute the slope of the supply curve because the 1995–1997 and the 1998 market equilibria both fall along the initial supply curve, labeled S_{1997} in Figure 2.23.

$$h = \text{slope of } S_{1997} = \frac{\Delta Q^*}{\Delta P^*} = \frac{33 \text{ million} - 30 \text{ million}}{10 - 9} = 3 \text{ million}$$

Therefore, the shift in demand *identifies* the slope of the supply curve. It may seem curious that it takes a shift in demand to provide information about the supply curve, but on reflection, it really isn't that surprising. The shift in demand moves the market along a particular supply curve and thus tells us how sensitive the quantity supplied is to the price. Similarly, the shift in the market supply of crushed stone caused by the rise in wage rates identifies the slope of the demand curve, labeled D_{1997} in Figure 2.23.

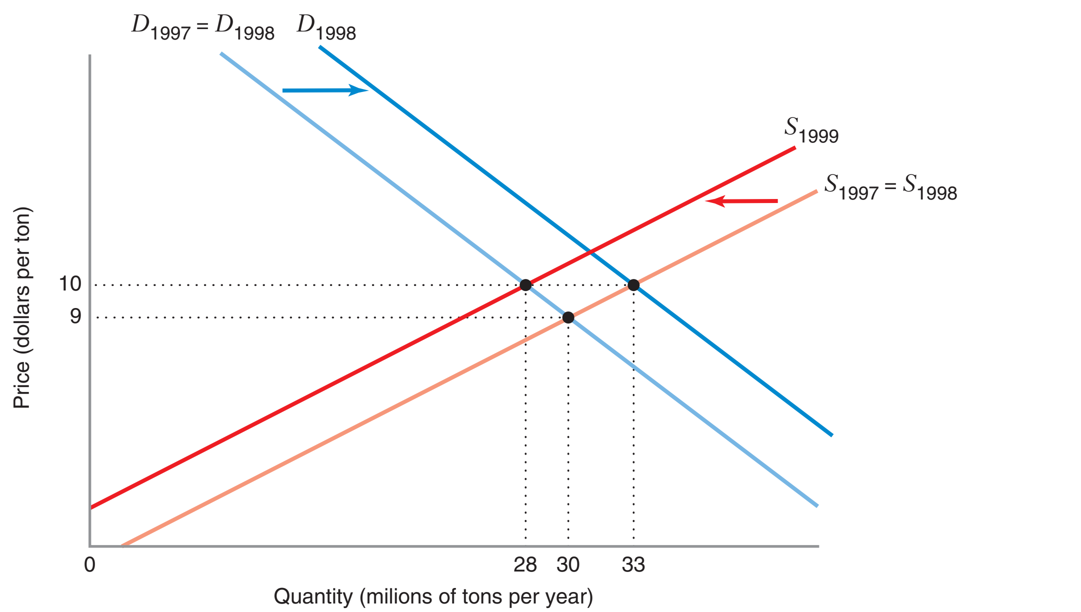


FIGURE 2.23 Identifying Demand and Supply Curves from Observed Price and Quantity Changes
The market for crushed stone is in equilibrium during the years 1995 through 1997. In 1998, the 1-year burst of highway construction activity shifts the demand curve rightward to D_{1998}. The market moves along the supply curve S_{1997}, so the change in equilibrium price and quantity identifies the slope of the supply curve S_{1997}. In 1999, the demand curve shifts back to D_{1997}, but the supply curve shifts leftward to S_{1999} due to an increase in the wages of workers in the crushed stone industry. The market thus moves along the demand curve D_{1997}, so the change in the equilibrium price and quantity identifies the slope of the demand curve D_{1997}.

Note that the burst of highway construction subsided in 1999, so in that year the demand curve for crushed stone reverted to its initial position, and the shift in supply (also assumed to be parallel) thus moved the market along the demand curve D_{1997}.

$$-b = \text{slope of } D_{1997} = \frac{\Delta Q^*}{\Delta P^*} = \frac{28 \text{ million} - 30 \text{ million}}{10 - 9} = -2 \text{ million}$$

Note the unifying logic that was used in both calculations. Knowing that one curve shifted while the other did not allowed us to calculate the slope of the curve that did not shift.

Having calculated the slopes of the demand and supply curves, we can now work backward to calculate the intercepts a and f of the demand and supply curves for 1999. Since we know that 28 million tons were sold at \$10 per ton during those years, the following equations must hold:

$$28 = a - (2 \times 10) \qquad \text{(demand)}$$
$$28 = f + (3 \times 10) \qquad \text{(supply)}$$

Solving these equations gives $a = 48$ and $f = -2$. Thus, the demand and supply curves for this market in 1999 were $Q^d = 48 - 2P$ and $Q^s = -2 + 3P$.

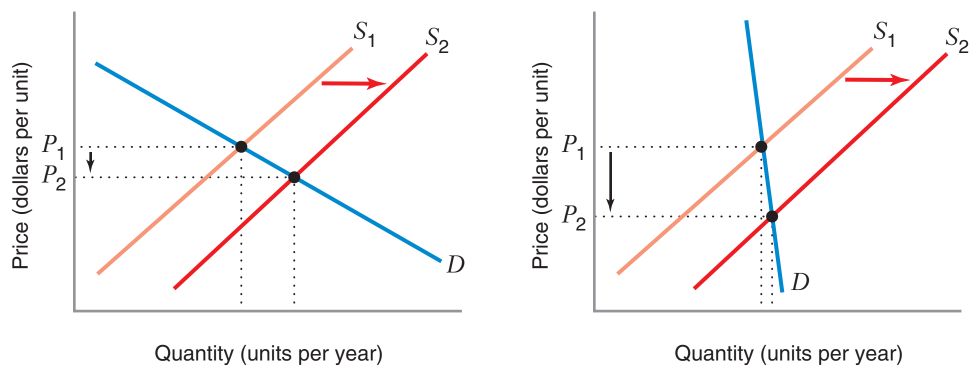
Having identified equations for the demand and supply curves, we can now use them to forecast how changes in demand or supply will affect the equilibrium price and quantity. For example, suppose we expected that in the year 2000 another burst of new road construction would increase the demand for crushed stone by 15 million tons per year no matter what the price. Suppose, further, that supply conditions were expected to resemble those in 1999. At equilibrium, $Q^d = Q^s$, so we could forecast the equilibrium price by solving the equation $48 - 2P + 15 = -2 + 3P$, which gives $P = \$13$ per ton. The equilibrium quantity in the year 2000 would be expected to equal $-2 + 3(13) = 37$ million tons. Our back-of-the-envelope analysis provides us with a "quick and dirty" way to forecast future price and quantity movements in this market.

There is an important limitation to this analysis. We can identify the slope of the demand curve by a shift in supply only if the demand curve remains fixed, and we can identify the slope of the supply curve by a shift in demand only if the supply curve stays fixed. If both curves shift at the same time, then we are neither moving along a given demand curve nor a given supply curve, so changes in the equilibrium quantity and the equilibrium price cannot identify the slope of either curve.

IDENTIFYING THE PRICE ELASTICITY OF DEMAND FROM SHIFTS IN SUPPLY

In the preceding section, we used actual changes in prices and quantities to identify the equations of supply or demand curves. In some instances, however, we might not know the change in the equilibrium quantity for a product, but we might have a good idea about the extent to which its supply curve has shifted. (Business-oriented newspapers such as *The Wall Street Journal* or the *Financial Times* often carry reports about supply conditions in markets for agricultural products, metals, and energy products.) If we also know the extent to which the market price has changed (which is also widely reported for many markets), we can use this information to assess the degree to which the demand for the product is price elastic or inelastic.

Figure 2.24 illustrates this point. Panel (a) in Figure 2.24 shows that when demand is relatively elastic, a given shift in supply (from S_1 to S_2) would have a modest impact on the equilibrium price. But when demand is relatively inelastic, as in panel (b) in Figure 2.24, the same shift in supply would have a more pronounced impact on the equilibrium price. Figure 2.24 teaches us that when a modest change in supply has a large impact on the market price of a product, the demand for that product is most likely price inelastic. By contrast, when a large shift in supply for a product has a relatively small impact on the market price, demand for the product is likely to be relatively elastic.



(a) Effect on price of shift in supply when demand is relatively elastic

(b) Effect on price of shift in supply when demand is relatively inelastic

FIGURE 2.24 Effect of Supply Shift on Price Depends on the Price Elasticity of Demand
In (a) demand is relatively elastic, and a shift in supply would have a modest impact on price. In (b) demand is relatively inelastic, and the identical shift in supply has a more dramatic impact on the equilibrium price.

APPLICATION 2.8

The Price of Pepper

In early 1999, observers of the pepper market predicted that the world pepper crop would increase by 6 percent, primarily because of large increases in supply in India and Vietnam. Observers also expected that this increase in supply would drive prices down by as much as 40 or 50 percent, a remarkably large impact.[24] But large swings in pepper prices are not unusual. Figure 2.25 shows that between 1982 and 1994, the price of pepper fluctuated dramatically.[25] In particular, between 1987 and 1994, the price of pepper fell from $2.37 per pound to $0.56 per pound. Since the U.S. demand for pepper (the U.S. is the world's largest importer of pepper) probably does not change much from year to year, most of the fluctuations in the price of pepper are probably attributable to shifts in supply rather than to shifts in demand.[26] This was almost certainly true for the drop in pepper price between 1987 and 1994. By the early 1990s, new pepper plantings in countries such as Indonesia in the mid-1980s (when prices were high) had reached an age at which they yielded their most bountiful supply of pepper.

Why do changes in supply have such a large impact on the price of pepper? The logic of the preceding section tells us that the demand for pepper is probably quite inelastic. In fact, if we assume for the sake of illustration that the experts' forecasts for 1999 were correct, we can determine just how inelastic the demand for pepper must be. Figure 2.26 shows how.

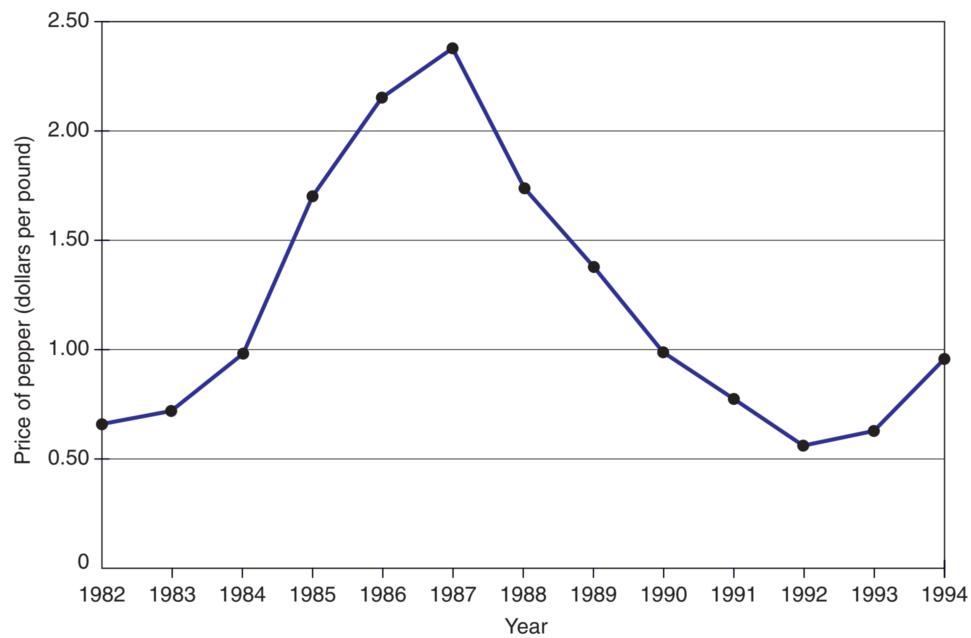


FIGURE 2.25 Price of Pepper, 1982–1994
Between 1982 and 1994, the price of pepper fluctuated greatly, reaching a high of $2.37 per pound in 1987 and a low of $0.56 a pound in 1992.

[24]These forecasts were reported in "Big Fall Expected This Year in World Pepper Prices," *Financial Times* (February 19, 1999). It turns out that the experts' forecasts were wrong. Unexpectedly high rainfall in 1999 caused a shortfall in the Indonesian pepper crop of nearly 40 percent and a shortfall in the Indian crop of nearly 30 percent. As a result, pepper prices increased rather than decreased in 1999. See "Rains Bring Pepper Shortfall," *Financial Times* (August 18, 1999), p. 28.

The increase in the supply of pepper by 6 percent is depicted as a rightward shift in the supply curve, from S_{1998} to S_{1999}. If the supply curve shifts outward by a given amount (6 percent), the equilibrium quantity demanded must increase, but by less than the amount of the supply shift, as Figure 2.26 shows. Thus, taking the experts' forecasts at face value, we can conclude the following:

- Percent change in equilibrium price of pepper ($\%\Delta P$) $= -45$ percent (the average of the experts' predictions).
- Percent change in the equilibrium quantity of pepper demanded ($\%\Delta Q$) is *no more* than 6 percent and *no less* than 0 percent.

Taken together, these forecasts imply that the price elasticity of demand $(\%\Delta Q)/(\%\Delta P)$ is between $0/(-45)$ and $6/(-45)$; that is, between 0 and -0.133. This tells us that the demand for pepper is quite inelastic. The conclusion that the demand for pepper is relatively price inelastic makes sense. Pepper is just a small fraction of a consumer's grocery budget or a restaurant's supply budget, and most of us who use pepper to season our food would be hard pressed to find a close substitute for it, so when the price of pepper goes up, the quantity of pepper demanded by households and by eating establishments probably does not change very much.

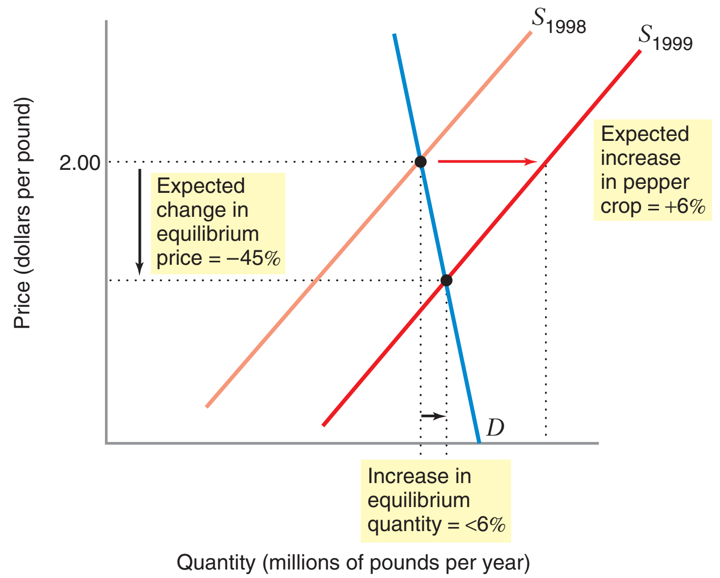


FIGURE 2.26 The Pepper Market between 1998 and 1999
Experts expected a 6 percent increase in the world pepper crop in 1999 as compared to 1998. This is reflected in a rightward shift in supply from S_{1998} to S_{1999} of 6 percent. Assuming that the demand curve D remains fixed, this rightward shift translates into an increase in equilibrium quantity of less than 6 percent. Experts also expected that pepper prices would drop by 45 percent. This implies that along the demand curve D, a 45 percent drop in price results in an increase in quantity of somewhere between 0 and 6 percent.

[25]These data come from Peter J. Buzzanell and Fred Gray, "The Spice Market in the United States: Recent Developments and Prospects," *Agricultural Information Bulletin*, Number 709, Foreign Agriculture Service, U.S. Department of Agriculture, July 1995.

[26]This is not to say that the demand curve for pepper did not shift at all, only that the shifts in demand were probably much less pronounced than the shifts in supply.

APPLICATION 2.9

The California Energy Crisis[27]

The California energy crisis has attracted attention from around the world. During the first four months of 2001, the average wholesale price of electricity was about 10 times the price in 1998 and 1999. Even at these high prices, many customers were forced to cut back on their consumption of electricity because of supply shortages. California's two largest electric utilities, Pacific Gas & Electric and Southern California Edison, were buying electricity at wholesale prices that were higher than the retail prices they were allowed to charge. The electric utility industry was threatened with bankruptcy. How did the crisis arise?

Figure 2.27 provides a simplified illustration of the structure of the electric power industry. Electricity is typically generated at plants that convert other forms of energy (such as nuclear power, hydroelectric power, natural gas, oil, coal, solar power, and wind) to electricity. In California, there were four large firms generating electricity, along with a number of smaller firms. The generators sell electricity at wholesale prices. It flows through the transmission grid, a large network that delivers electricity to local electric utilities and some large industrial users. Electric utilities then distribute the power to retail customers, including residential and business customers.

In the early 1990s the California electric power industry was heavily regulated. The California Public Utilities Commission (PUC) set electricity prices after reviewing production costs. Because production costs and prices were among the highest in the country, the PUC began a major review of the industry in 1993. After 4 years of highly politicized debate, a new set of complex rules emerged for California's electricity market. Wholesale prices were deregulated, but the PUC continued to set retail prices, holding them essentially fixed. Before the reform, investor-owned electric utilities produced electricity from generating plants they owned. Following the restructuring, the utilities were required to sell most of their generating plants and then obliged to buy power at the unregulated wholesale prices.

The reforms seemed to be working well until several events simultaneously shocked the electricity market between 1999 and early 2001. The supply of electricity in wholesale markets shifted to the left as the amount of power from hydroelectric generators fell by 50 percent, the price of natural gas rose sixfold, and power outages removed some generators from production. The amount of power that California could import from neighboring states also declined. The demand for electricity also shifted to the right, increasing by about 12 percent.

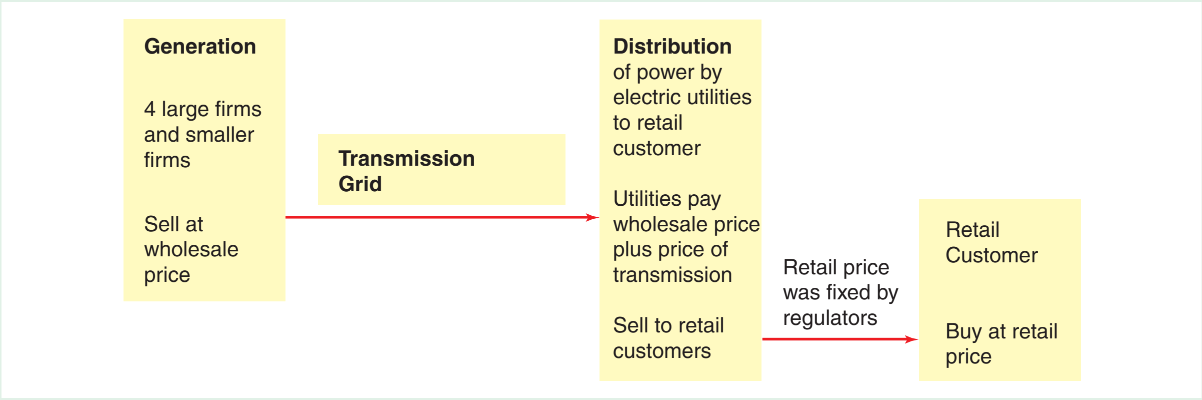


FIGURE 2.27 Structure of the Electric Power Industry in California
Electricity flows from firms that generate electric power; those firms sell the electricity at the wholesale price to large industrial users and to local electric power utilities. The utilities distribute the electricity to retail customers at the retail price.

[27]This discussion draws from Paul Joskow, "California's Energy Crisis," *Oxford Review of Economic Policy*, vol. 17, no. 3 (2001), pp. 365–388.

The steep slopes of the supply and demand curves in Figure 2.28 help to explain why wholesale prices rose so dramatically during the crisis. The supply of electricity is relatively inelastic, because California had severely limited the construction of new generating capacity over the past two decades. When generators needed to produce more electricity, they had to utilize older, less efficient plants many of which were fueled by natural gas. The demand for electricity is also relatively inelastic, because electricity is essential for many consumers and producers. Because the supply and demand curves were steeply sloped, the shifts in both curves led to a sharp increase in the price of electricity in wholesale markets in early 2001.

As the crisis unfolded, the state of California sought to ensure that the shortages experienced during the crisis would not occur in the future. It made a decision that threatened its financial viability, entering into long-term contracts to purchase electricity at very high prices, a move that it soon regretted. By the latter part of 2001, wholesale prices had returned to the levels prevailing before the crisis. The decline in prices in part reflected several developments that shifted the supply curve back to the right, as natural gas prices fell, several new plants began to produce in the summer of 2001, and significant generating capacity that had been unavailable earlier in the year returned to service. In addition, measures to conserve electricity during the crisis may have shifted the demand curve to the left, contributing further to a decline in prices.

While there were several flaws in the design of the public policy shaping the industry, two stand out above the others. First, because the PUC held retail prices at a low level, customers had little incentive to cut back their consumption of electricity, even though wholesale prices rose substantially. As Paul Joskow observed, "Competitive electricity markets will not work well if consumers are completely insulated from wholesale market price. . . . Not only did this drive the utilities to the point of insolvency after wholesale prices rose above the fixed retail price in June 2000, but it also made it very difficult for competing retail suppliers to attract customers or for consumers to respond to high prices by reducing consumption." Second, in the wake of the crisis there have been allegations that, with four large suppliers, wholesale markets might not have been competitive and that some producers might have strategically withdrawn capacity to drive prices higher. Some analysts have suggested that, prior to deregulation, the generating sector of the industry should have been restructured to have more, smaller generating firms to ensure that producers acted as price takers, and not price makers.

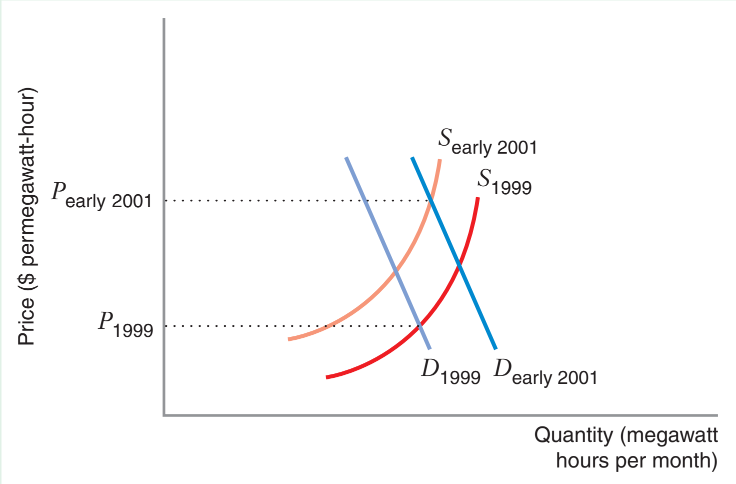


FIGURE 2.28 The California Energy Crisis: The Wholesale Market
Between 1999 and early 2001 the supply of electricity in wholesale markets shifted to the left as the supply of power from hydroelectric sources fell by 50 percent, the price of natural gas rose by 600 percent, and power outages increased by a factor of 10. The demand for electricity also shifted to the right. Because the supply and demand curves were steeply sloped, the shifts in both curves led to a sharp increase in the price of electricity in the wholesale market.

CHAPTER SUMMARY

- The market demand curve shows the quantity that consumers are willing to purchase at different prices. The market supply curve shows the quantity that producers are willing to sell at different prices. **(LBD Exercises 2.1 and 2.2)**
- Market equilibrium occurs at the price at which quantity supplied equals quantity demanded. At this price, the supply curve and the demand curve intersect. **(LBD Exercise 2.3)**
- Comparative statics analysis on the market equilibrium involves tracing through the effect of a change in exogenous variables, such as consumer income, the prices of other goods, or the prices of factors of production, on the market equilibrium price and quantity. **(LBD Exercise 2.4)**
- The price elasticity of demand measures the sensitivity of quantity demanded to price. It is the percentage change in quantity demanded per percentage change in price. **(LBD Exercise 2.5)**
- Commonly used demand curves include the constant elasticity demand curve and the linear demand curve. The price elasticity of demand is constant along a constant elasticity demand curve, while it varies along a linear demand curve. **(LBD Exercise 2.6)**
- A product's demand tends to be more price elastic when good substitutes are available and when the product represents a significant fraction of buyers' total expenditures. A product's demand tends to be less price elastic when it has few good substitutes, when it represents a small fraction of buyers' total expenditures, and when it is seen as a necessity by buyers.
- It is important to distinguish between market-level price elasticities of demand and brand-level price elasticities of demand. Demand can be price inelastic at the market level but highly price elastic at the brand level.
- Other key elasticities include the income elasticity of demand and the cross-price elasticity of demand.
- For many products, long-run demand is likely to be more price elastic than short-run demand. However, for durable goods, such as commercial aircraft, long-run demand is likely to be less price elastic than short-run demand.
- Similarly, long-run supply for many goods is likely to be more price elastic than short-run supply. However, for products that can be recycled, long-run supply can be less price elastic than short-run supply.
- Several back-of-the-envelope techniques can be used to fit demand and supply curves to observed market data. If you have price, quantity, and price elasticity of demand data, you can fit a demand curve to observed data. Information on price movements, coupled with knowledge that the demand curve has shifted, can be used to identify a stationary supply curve. Knowledge that the supply curve has shifted can be used to identify a stationary demand curve.

REVIEW QUESTIONS

1. Explain why a situation of excess demand will result in an increase in the market price. Why will a situation of excess supply result in a decrease in the market price?

2. Use supply and demand curves to illustrate the impact of the following events on the market for coffee:

a) The price of tea goes up by 100 percent.

b) A study is released that links consumption of caffeine to the incidence of cancer.

c) A frost kills half of the Colombian coffee bean crop.

d) The price of styrofoam coffee cups goes up by 300 percent.

3. Suppose we observe that the price of soybeans goes up, while the quantity of soybeans sold goes up as well. Use supply and demand curves to illustrate two possible explanations for this pattern of price and quantity changes.

4. A 10 percent increase in the price of automobiles reduces the quantity of automobiles demanded by 8 percent. What is the price elasticity of demand for automobiles?

5. A linear demand curve has the equation $Q = 50 - 100P$. What is the choke price?

6. Explain why we might expect the price elasticity of demand for speedboats to be more negative than the price elasticity of demand for light bulbs.

7. Many business travelers receive reimbursement from their companies when they travel by air, whereas vacation travelers typically pay for their trips out of their own pockets. How would this affect the comparison between the price elasticity of demand for air travel for business travelers versus vacation travelers?

8. Explain why the price elasticity of demand for an entire product category (such as yogurt) is likely to be less negative than the price elasticity of demand for a typical brand (such as Dannon) within that product category.

9. What does the sign of the cross-price elasticity of demand between two goods tell us about the nature of the relationship between those goods?

10. Explain why a shift in the demand curve identifies the supply curve and not the demand curve.

PROBLEMS

2.1. The demand for beer in Japan is given by the following equation: $Q^d = 700 - 2P - P_N + 0.1I$, where P is the price of beer, P_N is the price of nuts, and I is average consumer income.

a) What happens to the demand for beer when the price of nuts goes up? Are beer and nuts demand substitutes or demand complements?

b) What happens to the demand for beer when average consumer income rises?

c) Graph the demand curve for beer when $P_N = 100$ and $I = 10,000$.

2.2. Suppose the demand curve in a particular market is given by $Q = 5 - 0.5P$.

a) Plot this curve in a graph.

b) At what price will demand be unitary elastic?

2.3. The demand and supply curves for coffee are given by $Q^d = 600 - 2P$ and $Q^s = 300 + 4P$.

a) Plot the supply and demand curves on a graph and show where the equilibrium occurs.

b) Using algebra, determine the market equilibrium price and quantity of coffee.

2.4. Every year there is a shortage of Super Bowl tickets at the official prices P_0. Generally, a black market (known as scalping) develops in which tickets are sold for much more than the official price. Use supply and demand analysis to answer these questions:

a) What does the existence of scalping imply about the relationship between the official price P_0 and the equilibrium price?

b) If stiff penalties were imposed for scalping, how would the average black market price be affected?

2.5. You have decided to study the market for fresh-picked cherries. You learn that over the last 10 years, cherry prices have risen, while the quantity of cherries purchased has also risen. This seems puzzling because you learned in microeconomics that an increase in price usually decreases the quantity demanded. What might explain this seemingly strange pattern of prices and consumption levels?

2.6. Explain why a good with a positive price elasticity of demand must violate the law of demand.

2.7. Suppose that the quantity of corn supplied depends on the price of corn (P) and the amount of rainfall (R). The demand for corn depends on the price of corn and the level of disposable income (I). The equations describing the supply and demand relationships are $Q^s = 20R + 100P$ and $Q^d = 4000 - 100P + 10I$.

a) Sketch a graph of demand and supply curves that shows the effect of an *increase* in rainfall on the equilibrium price and quantity of corn.

b) Sketch a graph of demand and supply curves that shows the effect of a *decrease* in disposable income on the equilibrium price and quantity of corn.

2.8. Recall that when demand is perfectly inelastic, $\epsilon_{Q,P} = 0$.

a) Sketch a graph of a perfectly inelastic demand curve.

b) Suppose the supply of 1961 Roger Maris baseball cards is perfectly inelastic. Suppose, too, that renewed interest in Maris's career caused by Mark McGwire and Sammy Sosa's quest to break his home run record in 1998 caused the demand for 1961 Maris cards to go up. What will happen to the equilibrium price? What will happen to the equilibrium quantity of Maris baseball cards bought and sold?

2.9. Consider a linear demand curve, $Q = 350 - 7P$.

a) Derive the inverse demand curve corresponding to this demand curve.

b) What is the choke price?

c) What is the price elasticity of demand at $P = 50$?

2.10. A firm currently charges a price of $100 per unit of output, and its revenue (price multiplied by quantity) is $70,000. At that price it faces an elastic demand ($\epsilon_{Q,P} < -1$). If the firm were to raise its price by $2 per unit, which of the following levels of output could the firm possibly expect to see? Explain.

a) 400

b) 600

c) 800

d) 1000

2.11. Gina usually pays a price between $5 and $7 per gallon of ice cream. Over that range of prices, her monthly total expenditure on ice cream increases as the price decreases. What does this imply about her price elasticity of demand for ice cream?

2.12. For each of the following, discuss whether you expect the elasticity (of demand or of supply, as specified) to be greater in the long run or the short run.

a) The supply of seats in the local movie theater.

b) The demand for eye examinations at the only optometrist in town.

c) The demand for cigarettes.

2.13. Consider the following demand and supply relationships in the market for golf balls: $Q^d = 90 - 2P - 2T$ and $Q^s = -9 + 5P - 2.5R$, where T is the price of titanium, a metal used to make golf clubs, and R is the price of rubber.

a) If $R = 2$ and $T = 10$, calculate the equilibrium price and quantity of golf balls.

b) At the equilibrium values, calculate the price elasticity of demand and the price elasticity of supply.

c) At the equilibrium values, calculate the cross-price elasticity of demand for golf balls with respect to the price of titanium. What does the sign of this elasticity tell you about whether golf balls and titanium are substitutes or complements?

2.14. For the following pairs of goods, would you expect the cross-price elasticity of demand to be positive, negative, or zero? Briefly explain your answers.

a) Tylenol and Advil

b) DVD players and VCRs

c) Hot dogs and buns

2.15. Suppose that the market for air travel between Chicago and Dallas is served by just two airlines, United and American. An economist has studied this market and has estimated that the demand curves for round-trip tickets for each airline are as follows:

$$Q_U^d = 10{,}000 - 100P_U + 99P_A \quad \text{(United's demand)}$$

$$Q_A^d = 10{,}000 - 100P_A + 99P_U \quad \text{(American's demand)}$$

where P_U is the price charged by United, and P_A is the price charged by American.

a) Suppose that both American and United charge a price of $300 each for a round-trip ticket between Chicago and Dallas. What is the price elasticity of demand for United flights between Chicago and Dallas?

b) What is the market-level price elasticity of demand for air travel between Chicago and Dallas when both airlines charge a price of $300? (*Hint:* Because United and American are the only two airlines serving the Chicago–Dallas market, what is the equation for the total demand for air travel between Chicago and Dallas, assuming that the airlines charge the same price?)

2.16. You are given the following information:

- Price elasticity of demand for cigarettes at current prices is -0.5.
- Current price of cigarettes is $0.05 per cigarette.
- Cigarettes are being purchased at a rate of 10 million per year.

Find a linear demand that fits this information, and graph that demand curve.

2.17. In each of the following pairs of goods, identify the one which you would expect to have a greater price elasticity of demand. Briefly explain your answers.

a) Butter versus eggs

b) Trips by your congressman to Washington (say, to vote in the House) versus vacation trips by you to Hawaii

c) Orange juice in general versus the Tropicana brand of orange juice

2.18. In a city, the price for a trip on local mass transit (such as the subway or city buses) has been 10 pesos for a number of years. Suppose that the market for trips is characterized by the following demand curves: in the long run: $Q = 30 - 2P$; in the short run: $Q = 15 - P/2$. Verify that the long-run demand curve is "flatter" than the short-run curve. What does this tell you about the sensitivity of demand to price for this good? Discuss why this is the case.

2.19. Consider the following sequence of events in the U.S. market for strawberries during the years 1998–2000:

- 1998: Uneventful. The market price was $5.00 per bushel, and 4 million bushels were sold.
- 1999: There was a scare over the possibility of contaminated strawberries from Michigan. The market price was $4.50 per bushel, and 2.5 million bushels were sold.
- 2000: By the beginning of the year, the scare over contaminated strawberries ended when the media reported that the initial reports about the contamination were a hoax. A series of floods in the Midwest, however, destroyed significant portions of the strawberry fields in Iowa, Illinois, and Missouri. The market price was $8.00 per bushel, and 3.5 million bushels were sold.

Find linear demand and supply curves that are consistent with this information.

APPENDIX: Price Elasticity of Demand along a Constant Elasticity Demand Curve

In this section, we show that the point price elasticity of demand is the same along a constant elasticity demand curve of the form $Q = aP^{-b}$. For this demand curve,

$$\frac{dQ}{dP} = -baP^{-(b+1)}$$

Forming the expression for the point elasticity of demand, we have

$$\begin{aligned}
\epsilon_{Q,P} &= \frac{dQ}{dP}\frac{P}{Q} \\
&= -baP^{-(b+1)} \times \frac{P}{aP^{-b}} \text{ (substituting in the expression for } Q\text{)} \\
&= -b \text{ (after canceling terms)}
\end{aligned}$$

This shows that the price elasticity of demand for the constant elasticity demand curve is simply the exponent in the equation of the demand curve, $-b$. (For more on the use of derivatives, see the Mathematical Appendix at the end of the book.)