2 Supply and Demand

Talk is cheap because supply exceeds demand.

CHALLENGE

Quantities and Prices of Genetically Modified Foods

Countries around the globe are debating whether to permit firms to grow or sell genetically modified (GM) foods, which have their DNA altered through genetic engineering rather than through conventional breeding.[1] The introduction of GM techniques can affect both the quantity of a crop farmer's supply and whether consumers want to buy that crop. Using GM techniques, farmers can produce more output at a given cost. Common GM crops include canola, corn, cotton, rice, soybean, and sugar beet.

At least 29 countries grow GM food crops, which are mostly herbicide-resistant varieties of corn (maize), soybean, and canola (oilseed rape). Developing countries grow more GM crops than developed countries, though the United States plants 40% of worldwide GM acreage. The largest GM-producing country is the United States, followed by Brazil, Argentina, India, Canada, and China.

According to some polls, 70% of consumers in Europe object to GM foods. Fears cause some consumers to refuse to buy a GM crop. Consumers in other countries, such as the United States, are less concerned about GM foods. Only about one in six Americans care "a great deal" about GM foods. However, even in the United States, a 2017 ABC poll found that 52% of U.S. consumers believe that GM foods are generally unsafe to eat. The U.S. National Academy of Science reported that it could find no evidence to support claims that genetically modified organisms are dangerous for either the environment or human health. A letter signed by 131 Nobel Prize winners concludes that these fears are unjustified.

Nonetheless, as of 2018, 64 nations require labeling of GM foods, including European Union countries, Japan, Australia, Brazil, Russia, China, and the United States. Consumers are unlikely to avoid GM crops if products are unlabeled.

Will the use of GM seeds lead to lower prices and more food sold? What happens to prices and quantities sold if many consumers refuse to buy GM crops? We will use the models in this chapter to answer these questions at the end of the chapter.

To analyze questions concerning the price and quantity responses from introducing new products or technologies, imposing government regulations or taxes, or other events, economists may use the *supply-and-demand model*. When asked, "What is the most important

[1]Sources for Applications and Challenges appear at the back of the book.

thing you know about economics?" many people reply, "Supply equals demand." This statement is shorthand for one of the simplest yet most powerful models of economics. The supply-and-demand model describes how consumers and suppliers interact to determine the price and the quantity of a good or service. To use the model, you need to determine three things: buyers' behavior, sellers' behavior, and their interaction.

After reading that grandiose claim, you might ask, "Is that all there is to economics? Can I become an expert economist that fast?" The answer to both questions, of course, is no. In addition, you need to learn the limits of this model and which other models to use when this one does not apply. (You must also learn the economists' secret handshake.)

Even with its limitations, the supply-and-demand model is the most widely used economic model. It provides a good description of how markets function, and it works particularly well in markets that have many buyers and sellers, such as most agricultural and labor markets. Like all good theories, the supply-and-demand model can be tested—and possibly proven false. But in markets where it is applicable, it allows us to make accurate predictions easily.

In this chapter, we examine eight main topics

1. **Demand.** The quantity of a good or service that consumers demand depends on price and other factors such as consumers' incomes and the prices of related goods.
2. **Supply.** The quantity of a good or service that firms supply depends on price and other factors such as the cost of inputs that firms use to produce the good or service.
3. **Market Equilibrium.** The interaction between the consumers' demand curve and the firms' supply curve determines the market price and quantity of a good or service that is bought and sold.
4. **Shocking the Equilibrium: Comparative Statics.** Changes in a factor that affect demand (such as consumers' incomes), supply (such as a rise in the price of inputs), or a new government policy (such as a new tax) alter the market or *equilibrium* price and quantity of a good.
5. **Elasticities.** Given estimates of summary statistics called *elasticities*, economists can forecast the effects of changes in taxes and other factors on market price and quantity.
6. **Effects of a Sales Tax.** How a sales tax increase affects the price and quantity of a good, and whether the tax falls more heavily on consumers or on suppliers, depend on the supply and demand curves.
7. **Quantity Supplied Need Not Equal Quantity Demanded.** If the government regulates the prices in a market, the quantity supplied might not equal the quantity demanded.
8. **When to Use the Supply-and-Demand Model.** The supply-and-demand model applies to competitive markets only.

2.1 Demand

The **quantity demanded** is the amount of a good that consumers are *willing* to buy at a given price during a specified period (such as a day or a year), holding constant the other factors that influence purchases. The quantity demanded of a good or service can exceed the quantity actually sold. For example, as a promotion, a local store might sell Lindt Excellence Dark Chocolate Bar with A Touch of Sea Salt for $1 each today only. At that low price, you might want to buy 10 bars, but because the store has only

5 remaining, you can buy at most 5 bars. The quantity you demand is 10 bars—it's the amount you want—even though the amount you actually buy is 5.

Potential consumers decide how much of a good or service to buy based on its price, which is expressed as an amount of money per unit of the good (for example, dollars per pound), and many other factors, including consumers' tastes, information, and income; prices of other goods; and government actions. Before concentrating on the role price plays in determining demand, let's look briefly at some of the other factors.

Consumers make purchases based on their *tastes*. Consumers do not purchase foods they dislike, works of art they don't appreciate, or clothes they think are unfashionable or uncomfortable. However, advertising can influence people's tastes.

Similarly, *information* (or misinformation) about the uses of a good affects consumers' decisions. A few years ago, when many consumers were convinced that oatmeal could lower their cholesterol level, they rushed to grocery stores and bought large quantities of oatmeal. (They even ate it until they remembered that they disliked the taste.)

The *prices of other goods* also affect consumers' purchase decisions. Before deciding to buy a pair of Levi's jeans, you might check the prices of other brands. If the price of a close *substitute*—a product that you think is similar or identical to the jeans you are considering purchasing—is much lower than the price of the Levi's, you might buy that other brand instead. Similarly, the price of a *complement*—a good that you like to consume at the same time as the product you are considering buying—could affect your decision. If you only eat pie with ice cream, the higher the price of ice cream, the less likely you are to buy pie.

People's incomes play a major role in determining what and how much of a good or service they purchase. A person who suddenly inherits great wealth might purchase a Mercedes and other luxury items, and may be less likely to buy do-it-yourself repair kits.

Government rules and regulations affect people's purchase decisions. Sales taxes increase the price that a consumer must spend on a good, and government-imposed limits on the use of a good can affect demand. For example, if a city government bans the use of skateboards on its streets, skateboard sales fall.[2]

Other factors can also affect the demand for specific goods. Some people are more likely to buy a pair of $200 shoes if their friends do. The demand for small, dying evergreen trees is substantially higher in December than in other months.

Although many factors influence demand, economists usually concentrate on how a product's price affects the quantity demanded. To determine how a change in price affects the quantity demanded, economists must hold constant other factors, such as income and tastes, which affect the quantity demanded.

The Demand Function

The **demand function** shows the correspondence between the quantity demanded, price, and other factors that influence purchases. Some other factors that may influence the quantity demanded include income, substitutes, and complements. A **substitute** is a good or service that may be consumed instead of another good or service. For many people, tea is a substitute for coffee. A **complement** is a good or service that is jointly consumed with another good or service. For example, many people drink coffee with sugar.

[2]When a Mississippi woman attempted to sell her granddaughter for $2,000 and a car, state legislators were horrified to discover that they had no law on the books prohibiting the sale of children and quickly passed such a law. (Mac Gordon, "Legislators Make Child-Selling Illegal," *Jackson Free Press*, March 16, 2009.)

Let's examine the demand function for coffee. The quantity of coffee demanded, Q, varies with the price of coffee, p, the price of sugar, p_s, and consumers' income, Y, so the coffee demand function, D, is

$$Q = D(p, p_s, Y). \tag{2.1}$$

We assume that any other factors that are not explicitly listed in the demand function are irrelevant (such as the price of llamas in Peru) or constant (such as the prices of substitutes and complements, tastes, and consumer information).

Equation 2.1 is a general functional form—it does not specify exactly how Q varies with the explanatory variables, p, p_s, and Y. An estimated world demand function for green (unroasted) coffee beans is[3]

$$Q = 8.56 - p - 0.3p_s + 0.1Y, \tag{2.2}$$

where Q is the quantity of coffee in millions of tons per year, p is the price of coffee in dollars per pound (lb), p_s is the price of sugar in dollars per lb, and Y is the average annual household income in high-income countries in thousands of dollars.

Usually, we're primarily interested in the relationship between the quantity demanded and the price of the good. That is, we want to know the relationship between the quantity demanded and price, holding all other factors constant. For example, given that the price of sugar, p_s, is \$0.20 per lb and the average income, Y, is \$35 thousand per year, we can substitute those values into Equation 2.2 and write the quantity demanded as a function of only the price of coffee:

$$\begin{aligned} Q &= 8.56 - p - 0.3p_s + 0.1Y \\ &= 8.56 - p - (0.3 \times 0.2) + (0.1 \times 35) \\ &= 12 - p. \end{aligned} \tag{2.3}$$

We can graphically show this relationship, $Q = D(p) = 12 - p$, between the quantity demanded and price. A **demand curve** is a plot of the demand function that shows the quantity demanded at each possible price, holding constant the other factors that influence purchases. Figure 2.1 shows the estimated demand curve, D, for coffee. (Although this estimated demand curve is a straight line, demand curves can be smooth curves or wavy lines.) By convention, the vertical axis of the graph measures the price, p, per unit of the good, which in our coffee example is dollars per lb. The horizontal axis measures the quantity, Q, of the good, per physical measure of the good per period, which in this case is million tons per year.[4]

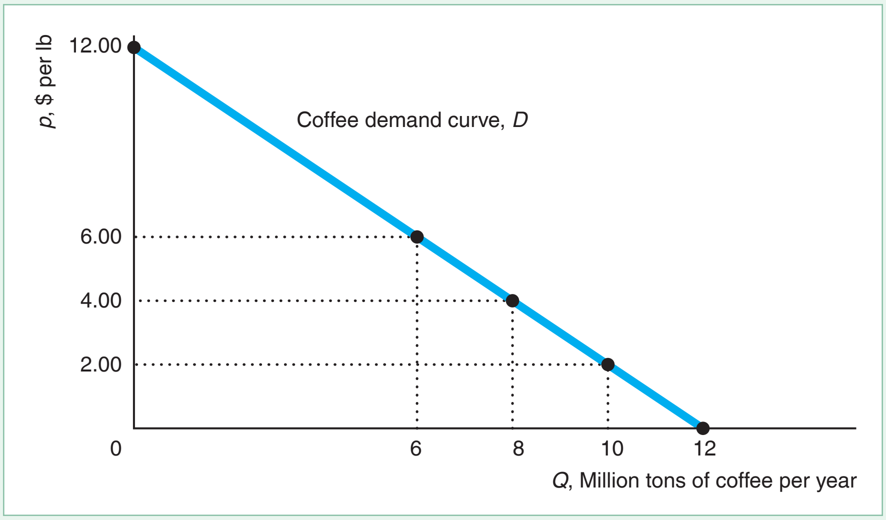
---

[3]Because prices, quantities, and other factors change simultaneously over time, economists use statistical techniques to hold the effects of factors other than the price of the good constant so that they can determine how price affects the quantity demanded (see Regression Appendix at the back of the book). As with any estimate, the demand curve estimates are probably more accurate in the observed range of prices than at very high or very low prices. I estimated this model using data from the Food and Agriculture Organization, *Commodity Review and Outlook*; International Coffee Organization, **www.ico.org/new_historical.asp**; International Cocoa Organization, *The World Cocoa Economy: Past and Present* (July 2012); and World Bank, *World Development Indicators*.

[4]Economists typically do not state the relevant physical and period measures unless these measures are particularly useful in context. I'll generally follow this convention and refer to the price as, say, \$2 (with the "per lb" understood) and the quantity as 10 (with the "million tons per year" understood).

Figure 2.1 A Coffee Demand Curve

The estimated global demand curve, D, for coffee shows the relationship between the quantity demanded per year and the price per lb. The downward slope of the demand curve shows that, holding other factors that influence demand constant, consumers demand a smaller quantity of a good when its price is high and a larger quantity when the price is low. A change in price causes a *movement along the demand curve*. For example, an increase in the price of coffee causes consumers to demand a smaller quantity of coffee.



If we set the quantity equal to zero in Equation 2.3, $Q = 12 - p = 0$, we find that $p = \$12$. That is, the demand curve, D, hits the price (vertical) axis at \$12, indicating that no quantity is demanded when the price is \$12 per lb or higher. If we set the price equal to zero in Equation 2.3, $Q = 12 - 0 = 12$, we learn that the demand curve hits the horizontal quantity axis at 12 million tons. That is the amount of coffee that people would consume if coffee were free.

By plugging any particular value for p into the demand equation, we can determine the corresponding quantities. For example, if $p = \$2$, then $Q = 12 - 2 = 10$, as Figure 2.1 shows.

A Change in a Product's Price Causes a Movement Along the Demand Curve. The demand curve in Figure 2.1 shows that if the price decreases from \$6 to \$4 per lb, the quantity consumers demand increases by 2 units (million tons), from 6 to 8. These changes in the quantity demanded in response to changes in price are *movements along the demand curve*. The demand curve is a concise summary of the answers to the question "What happens to the quantity demanded as the price changes, when all other factors are held constant?"

One of the most important empirical findings in economics is the **Law of Demand**: Consumers demand more of a good the lower its price, holding constant tastes, the prices of other goods, and other factors that influence the amount they consume.[5] One way to state the Law of Demand is that the demand curve slopes downward, as in Figure 2.1.

Because the derivative of the demand function with respect to price shows the *movement along the demand curve as we vary price*, another way to state the Law of Demand is that this derivative is negative: A higher price results in a lower quantity demanded. If the demand function is $Q = D(p)$, then the Law of Demand says that $dQ/dp < 0$, where dQ/dp is the derivative of the D function with respect to p. (Unless we state otherwise, we assume that all demand and other functions are

[5]In Chapter 4, we show that theory does not require that the Law of Demand holds; however, available empirical evidence strongly supports the Law of Demand.

continuous and differentiable everywhere.) The derivative of the quantity of coffee demanded with respect to its price in Equation 2.3 is

$$\frac{\mathrm{d}Q}{\mathrm{d}p} = -1,$$

which is negative, so the Law of Demand holds. Given $\mathrm{d}Q/\mathrm{d}p = -1$, a small change in the price (measured in dollars per lb) causes an equal unit decrease in the quantity demanded (measured in million tons per year).

This derivative gives the change in the quantity demanded in response to an infinitesimal change in the price. In general, if we look at a discrete, relatively large increase in the price, the change in the quantity might not be proportional to the change for a small increase in the price. However, here the derivative is a constant that does not vary with the price, so the same derivative holds for large and small price changes.

For example, let the price increase from $p_1 = \$2$ to $p_2 = \$4$. That is, the change in the price $\Delta p = p_2 - p_1 = \$4 - \$2 = \$2$. (The Δ symbol, the Greek letter capital delta, means "change in" the following variable, so Δp means "change in price.") As Figure 2.1 shows, the corresponding quantities are $Q_1 = 10$ and $Q_2 = 8$. Thus, if $\Delta p = \$2$, then the change in the quantity demanded is $\Delta Q = Q_2 - Q_1 = 8 - 10 = -2$.

Because we put price on the vertical axis and quantity on the horizontal axis, the slope of the demand curve is the reciprocal of the derivative of the demand function: slope $= \mathrm{d}p/\mathrm{d}Q = 1/(\mathrm{d}Q/\mathrm{d}p)$. In our example, the slope of demand curve D in Figure 2.1 is $\mathrm{d}p/\mathrm{d}Q = 1/(\mathrm{d}Q/\mathrm{d}p) = 1/(-1) = -1$. We can also calculate the slope in Figure 2.1 using the rise-over-run formula and the numbers we just calculated (because the slope is the same for small and for large changes):

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta p}{\Delta Q} = \frac{\$1 \text{ per lb}}{-1 \text{ million tons per year}} = -\$1 \text{ per million tons per year.}$$

This slope tells us that to sell one more unit (a million tons per year) of coffee, the price (per lb) must fall by \$1.

A Change in Another Factor Causes the Demand Curve to Shift. If a demand curve shows how a price change affects the quantity demanded, holding all other factors that affect demand constant, how can we use demand curves to show the effects of a change in one of these other factors, such as the income? One solution is to draw the demand curve in a three-dimensional diagram with the price of coffee on one axis, the income on a second axis, and the quantity of coffee on the third axis. But just thinking about drawing such a diagram probably makes your head hurt.

Economists use a simpler approach to show how a change in a factor other than the price of a good affects its demand. A change in any factor except the price of the good itself causes a *shift of the demand curve* rather than a *movement along the demand curve*.

If the average income rises and the price of coffee remains constant, people buy more coffee. Suppose that the average income rises from \$35,000 per year to \$50,000, an increase of \$15,000. Using the demand function in Equation 2.2, we can calculate the new coffee demand function relating the quantity demanded to only its price:[6]

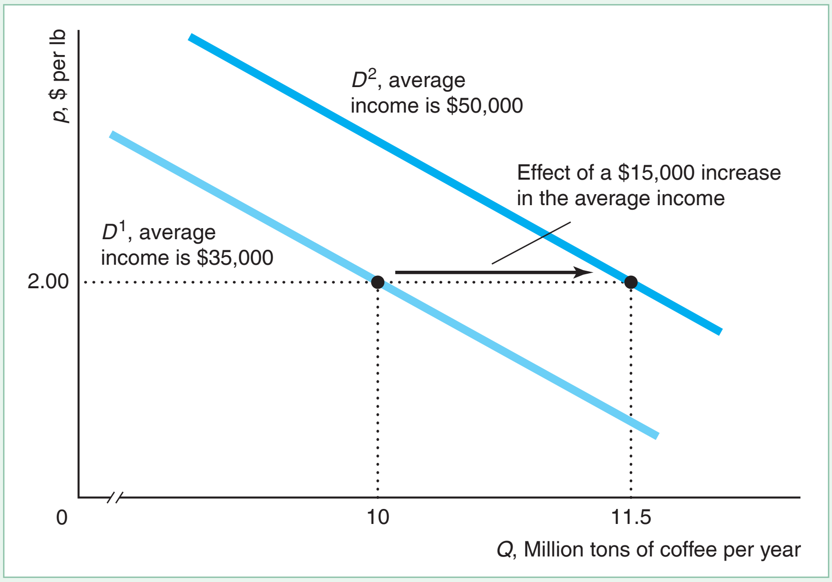
$$Q = 13.5 - p. \tag{2.4}$$

Figure 2.2 shows that the higher income causes the coffee demand curve to shift 1.5 units to the right from D^1 (corresponding to the demand function in Equation 2.3) to D^2 (corresponding to the demand function in Equation 2.4).

[6]Substituting $Y = 50$ and $p_s = 0.2$ into Equation 2.2, we find that $Q = 8.56 - p - (0.3 \times 0.2) + (0.1 \times 50) = 13.5 - p$.

Figure 2.2 A Shift of the Demand Curve

The global demand curve for coffee shifts to the right from D^1 to D^2 as average annual household income in high-income countries rises by \$15,000, from \$35,000 to \$50,000. At the higher income, more coffee is demanded at any given price.



Why does the demand function shift by 1.5 units (million tons per year)? Using the demand function Equation 2.2, we find that the partial derivative of the quantity of coffee demanded with respect to the income is $\partial Q/\partial Y = 0.1$. Thus, if the income increases by \$15 thousand, the quantity of coffee demanded rises by $0.1 \times 15 = 1.5$ units, holding all other factors constant.

To properly analyze the effects of a change in some variable on the quantity demanded, we must distinguish between a *movement along a demand curve* and a *shift of a demand curve*. A change in the *price of a good* causes a *movement along its demand curve*. A change in *any other factor besides the price of the good* causes a *shift of the demand curve*.

Summing Demand Functions

If we know the demand curve for each of two consumers, how do we determine the total or aggregate demand for the two consumers combined? The total quantity demanded at a given price is the sum of the quantity each consumer demands at that price.

We can use the demand functions to determine the total demand of several consumers. Suppose the demand function for Consumer 1 is $Q_1 = D^1(p)$, and the demand function for Consumer 2 is $Q_2 = D^2(p)$. At price p, Consumer 1 demands Q_1 units, Consumer 2 demands Q_2 units, and the total demand of both consumers is the sum of the quantities each demands separately:

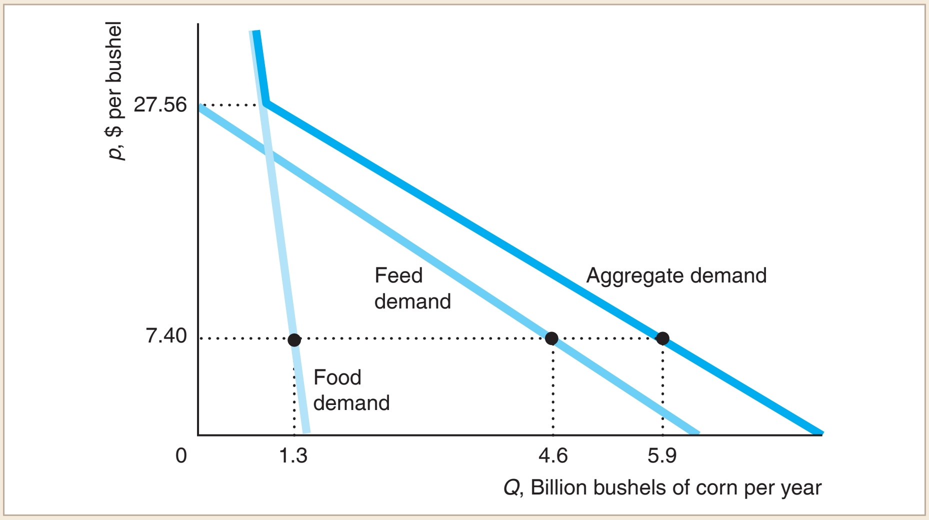
$$Q = Q_1 + Q_2 = D^1(p) + D^2(p).$$

We can generalize this approach to look at the total demand for three or more consumers.

APPLICATION

Aggregating Corn Demand Curves

We illustrate how to sum individual demand curves to get an aggregate demand curve graphically using estimated demand curves for corn (McPhail and Babcock, 2012). The figure shows the U.S. feed demand (the use of corn to feed animals) curve, the U.S. food demand curve, and the aggregate demand curve from these two sources.[7]



To derive the sum of the quantity demanded for these two uses at a given price, we add the quantities from the individual demand curves at that price. That is, we add the demand curves horizontally. At the 2012 average price for corn, \$7.40, the quantity demanded for food is 1.3 billion bushels per year and the quantity demanded for feed is 4.6 billion bushels. Thus, the total quantity demanded at that price is $Q = 1.3 + 4.6 = 5.9$ billion bushels.

When the price of corn exceeds \$27.56 per bushel, farmers stop using corn for animal feed, so the quantity demanded for this use equals zero. As a result, the total demand curve is the same as the food demand curve at prices above \$27.56.

2.2 Supply

To determine the market price and quantity sold of a product, knowing how much consumers want is not enough. We also need to know how much firms want to supply at any given price.

The **quantity supplied** is the amount of a good that firms *want* to sell during a given period at a given price, holding constant other factors that influence firms' supply decisions, such as costs and government actions. Firms determine how much of a good to supply based on its price and other factors, including the costs of production and government rules and regulations. Usually, we expect firms to supply more at a higher price. Before concentrating on the role price plays in determining supply, we'll briefly consider the role of some other factors.

[7]For graphical simplicity, we do not show the other major U.S. demand curves for export, storage, and use in biofuels (ethanol). Thus, this aggregate demand curve is not the total demand curve for corn.

Production cost affects how much of a good a firm wants to sell. As a firm's cost rises, it is willing to supply less of the good, all else the same. In the extreme case where the firm's cost exceeds what it can earn from selling the good, the firm sells nothing. Thus, factors that affect cost also affect supply. For example, a technological advance that allows a firm to produce a good at a lower cost causes the firm to supply more of that good, all else the same.

Government rules and regulations affect how much firms want to sell or may sell. Taxes and many government regulations—such as those covering pollution, sanitation, and health insurance—alter the costs of production. Other regulations affect when and how firms may sell the product. For instance, most Western governments prohibit the sale of cigarettes and liquor to children. Also, most major cities around the world restrict the number of taxicabs.

The Supply Function

The **supply function** shows the correspondence between the quantity supplied, price, and other factors that influence the number of units offered for sale. Written generally (without specifying the functional form), the coffee supply function is

$$Q = S(p, p_c), \tag{2.5}$$

where Q is the quantity of coffee supplied, p is the price of coffee, and p_c is the price of cocoa (which is a key input in making chocolate). The land on which coffee is grown is also suitable for growing cocoa. When the price of cocoa rises, many coffee farmers switch to producing cocoa. Therefore, when the price of cocoa rises, the amount of coffee produced at any given price falls. The supply function, Equation 2.5, might also incorporate other factors such as wages, transportation costs, and the state of technology, but by leaving them out, we are implicitly holding them constant.

Our estimate of the supply function for coffee is

$$Q = 9.6 + 0.5p - 0.2p_c, \tag{2.6}$$

where Q is the quantity of coffee in millions of tons per year, p is the price of coffee in dollars per lb, and p_c is the price of cocoa in dollars per lb.

If we fix the cocoa price at \$3 per lb, we can rewrite the supply function in Equation 2.6 as solely a function of the coffee price. Substituting $p_c = \$3$ into Equation 2.5, we find that

$$Q = 9.6 + 0.5p - (0.2 \times 3) = 9 + 0.5p. \tag{2.7}$$

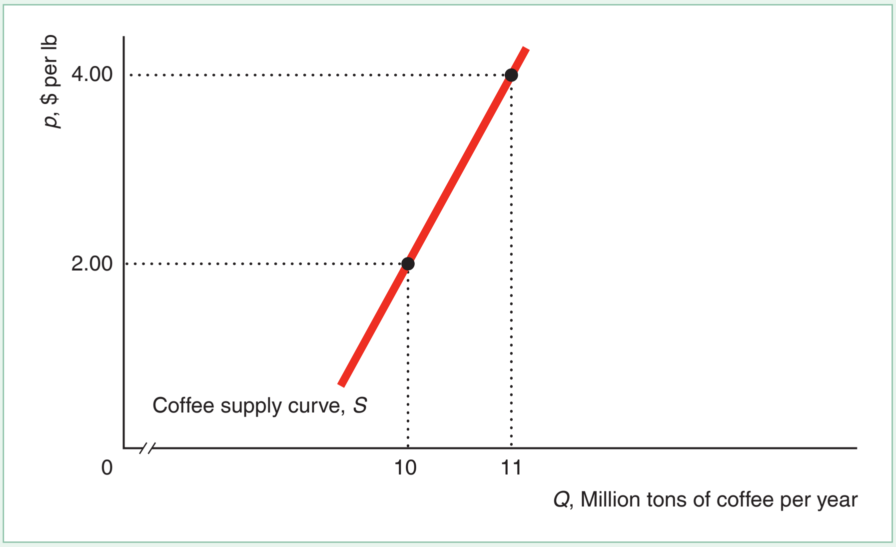
Because we hold fixed other variables that may affect the quantity supplied, such as costs and government rules, this supply function concisely answers the question "What happens to the quantity supplied as the price changes, holding all other factors constant?"

Corresponding to the supply function is a **supply curve**, which shows the quantity supplied at each possible price, holding constant the other factors that influence firms' supply decisions. Figure 2.3 shows the coffee supply curve, S, that corresponds to the supply function Equation 2.7. Because the supply function is linear, the corresponding supply curve is a straight line.

A Change in a Product's Price Causes a Movement Along the Supply Curve. As the price of coffee increases from \$2 to \$4 in Figure 2.3, holding other factors (the price of cocoa) constant, the quantity of coffee supplied increases from 10 to 11 million tons per year, which is a *movement along the supply curve*.

Figure 2.3 A Coffee Supply Curve

The estimated global supply curve, S, for coffee shows the relationship between the quantity supplied per year and the price per lb, holding constant cost and other factors that influence supply. The upward slope of this supply curve indicates that firms supply more coffee when its price is high and less when the price is low. An increase in the price of coffee causes firms to supply a larger quantity of coffee; any change in price results in a *movement along the supply curve*.



How much does an increase in the price affect the quantity supplied? Differentiating the supply function, Equation 2.7, with respect to price, we find that $dQ/dp = 0.5$. As this derivative is not a function of p, it holds for all price changes, both small and large. It shows that the quantity supplied increases by 0.5 units for each \$1 increase in price.

Because the derivative is positive, the supply curve S slopes upward in Figure 2.3. Although the Law of Demand states that the demand curve slope downward, we have *no* "Law of Supply" that requires the market supply curve to have a particular slope. The market supply curve can be upward sloping, vertical, horizontal, or downward sloping.

A Change in Another Factor Causes the Supply Curve to Shift. A change in a factor other than a product's price causes a *shift of the supply curve*. If the price of cocoa increases by \$3 from \$3 to \$6 per lb, the supply function for coffee becomes

$$Q = 9.6 + 0.5p - (0.2 \times 6) = 8.4 + 0.5p. \tag{2.8}$$

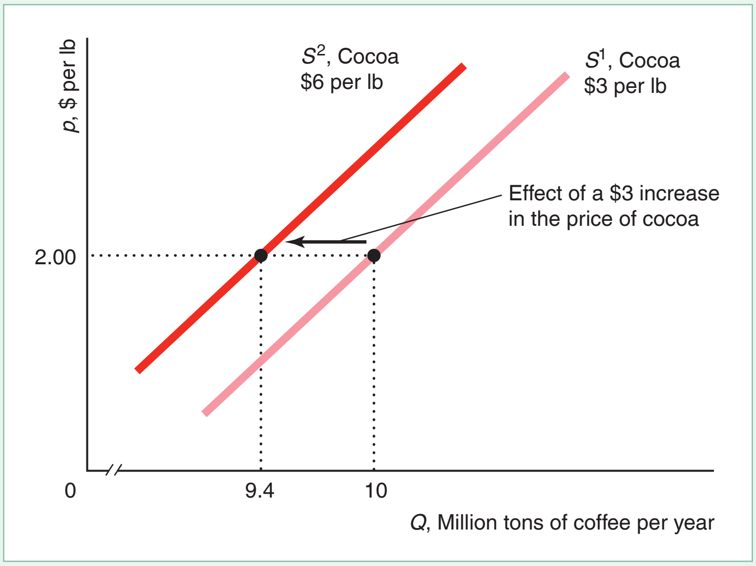
By comparing this supply function to the original one in Equation 2.7, $Q = 9 + 0.5p$, we see that the original supply curve, S^1, shifts 0.6 units to the left, to S^2 in Figure 2.4.

Alternatively, we can determine how far the supply curve shifts by partially differentiating the supply function Equation 2.6 with respect to the price of cocoa: $\partial Q/\partial p_c = -0.2$. This partial derivative holds for all values of p_c and hence for both small and large changes in p_c. Thus, a \$3 increase in the price of cocoa causes a $-0.2 \times 3 = -0.6$ units change in the quantity of coffee supplied at any price of coffee.

Again, it is important to distinguish between a *movement along a supply curve* and a *shift of the supply curve*. When the coffee price changes, the change in the quantity supplied reflects a *movement along the supply curve*. When costs, government rules, or other variables that affect supply change, the entire *supply curve shifts*.

Figure 2.4 A Shift of a Supply Curve

A \$3 per lb increase in the price of cocoa, which farmers can grow instead of coffee, causes the supply curve for coffee to shift left from S^1 to S^2. At the price of coffee of \$2 per lb, the quantity supplied falls from 10 million tons on S^1 to 9.4 million tons on S^2.



Summing Supply Functions

The total supply curve shows the total quantity of a product produced by all suppliers at each possible price. For example, the total supply curve of rice in Japan is the sum of the domestic and the foreign supply curves of rice.

Figure 2.5 shows the domestic supply curve, panel a, and foreign supply curve, panel b, of rice in Japan. The total supply curve, S in panel c, is the horizontal sum of the Japanese *domestic* supply curve, S^d, and the *foreign* supply curve, S^f. In the figure, the Japanese and foreign supplies are zero at any price equal to or less than $\underline{p}$, so the total supply is zero. At prices greater than $\underline{p}$, the Japanese and foreign supplies are positive, so the total supply is positive. For example, when the price is p^*, the quantity supplied by Japanese firms is Q_d^*, panel a, the quantity supplied by foreign firms is Q_f^*, panel b, and the total quantity supplied is $Q^* = Q_d^* + Q_f^*$, panel c. Because the total supply curve is the horizontal sum of the domestic and foreign supply curves, the total supply curve is flatter than each of the other two supply curves.

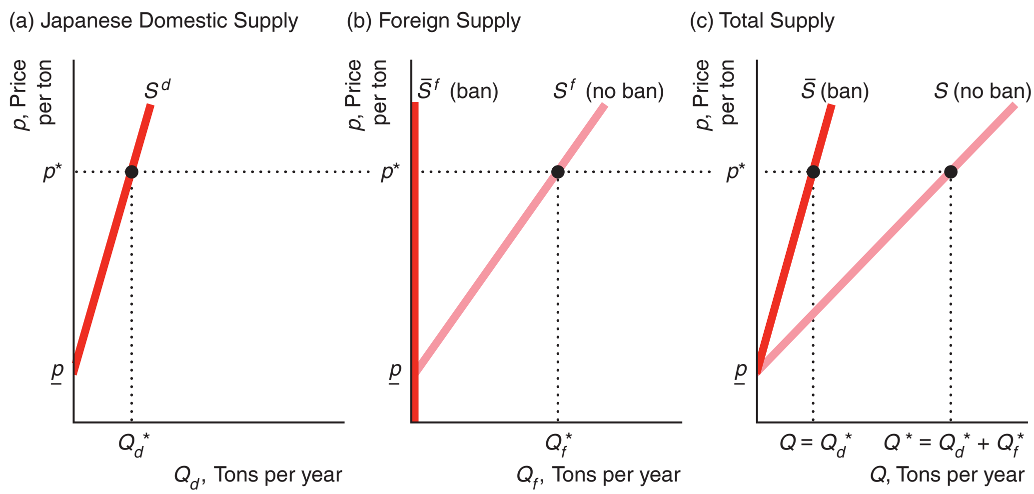
How Government Import Policies Affect Supply Curves

We can use this approach for deriving the total supply curve to analyze the effect of government policies on the total supply curve. Traditionally, the Japanese government has banned the importation of foreign rice. We want to determine how much less rice is supplied at any given price to the Japanese market because of this ban.

Without a ban, the foreign supply curve is S^f in panel b of Figure 2.5. A ban on imports eliminates the foreign supply, so the foreign supply curve after the ban is imposed, $\overline{S}^f$, is a vertical line at $Q_f = 0$. The import ban has no effect on the domestic supply curve, S^d, so the supply curve is the same as in panel a.

Figure 2.5 Total Supply: The Sum of Domestic and Foreign Supply

If foreigners are allowed to sell their rice in Japan, the total Japanese supply of rice, S, is the horizontal sum of the domestic Japanese supply, S^d, and the imported foreign supply, S^f. With a ban on foreign imports, the foreign supply curve, $\bar{S}^f$, is zero at every price, so the total supply curve, $\bar{S}$, is the same as the domestic supply curve, S^d.



Because the foreign supply with a ban, $\bar{S}^f$ in panel b, is zero at every price, the total supply with a ban, $\bar{S}$ in panel c, is the same as the Japanese domestic supply, S^d, at any given price. The total supply curve under the ban lies to the left of the total supply curve without a ban, S. Thus, the effect of the import ban is to rotate the total supply curve toward the vertical axis.

A limit that a government sets on the quantity of a foreign-produced good that may be imported is a **quota**. By absolutely banning the importation of rice, the Japanese government sets a quota of zero on rice imports. Sometimes governments set positive quotas, $\bar{Q} > 0$. The foreign firms may supply as much as they want, Q_f, as long as they supply no more than the quota: $Q_f \le \bar{Q}$.

2.3 Market Equilibrium

The supply and demand curves jointly determine the price and quantity at which goods and services are bought and sold. The demand curve shows the quantities that consumers want to buy at various prices, and the supply curve shows the quantities that firms want to sell at various prices. Unless the price is set so that consumers want to buy exactly the same amount that suppliers want to sell, either some buyers cannot buy as much as they want or some sellers cannot sell as much as they want.

When all traders are able to buy or sell as much as they want, we say that the market is in **equilibrium**: a situation in which no participant wants to change its behavior. At the *equilibrium price*, consumers want to buy the same quantity that firms want to sell. The quantity that consumers buy and firms sell at the equilibrium price is the *equilibrium quantity*.

Finding the Market Equilibrium

To illustrate how supply and demand curves determine the equilibrium price and quantity, we use our old friend, the coffee example. Figure 2.6 shows the supply, *S*, and the demand, *D*, curves for coffee. The supply and demand curves intersect at point *e*, the market equilibrium, where the equilibrium price is \$2 per lb and the equilibrium quantity is 10 million tons per year, which is the quantity that firms want to sell and the quantity that consumers want to buy at the equilibrium price.

We can determine the market equilibrium for coffee mathematically using the demand and supply functions, Equations 2.3 and 2.7. We use these two functions to solve for the equilibrium price at which the quantity demanded equals the quantity supplied (the equilibrium quantity).

The demand function in Equation 2.3 shows the relationship between the quantity demanded, Q_d, and the price:

$$Q_d = 12 - p.$$

The supply curve, Equation 2.7, tells us the relationship between the quantity supplied, Q_s, and the price:

$$Q_s = 9 + 0.5p.$$

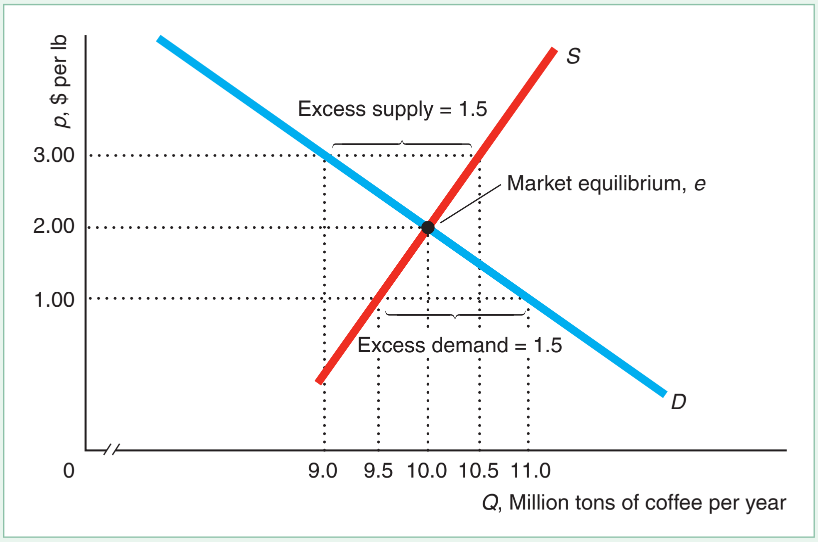
We want to find the price at which $Q_d = Q_s = Q$, the equilibrium quantity. Because the left sides of the two equations are the same in equilibrium, $Q_s = Q_d$, the right sides of the two equations must be equal as well:

$$9 + 0.5p = 12 - p.$$

Adding p to both sides of this expression and subtracting 9 from both sides, we find that $1.5p = 3$. Dividing both sides of this last expression by 1.5, we learn that the equilibrium price is $p = \$2$.

Figure 2.6 Market Equilibrium

The intersection of the supply curve, *S*, and the demand curve, *D*, for coffee determines the market equilibrium point, *e*, where $p = \$2$ per lb and $Q = 10$ million tons per year. At the lower price of $p = \$1$, the quantity demanded is 11, but the quantity supplied is only 9.5, so the excess demand is 1.5. At $p = \$3$, the price exceeds the equilibrium price. As a result, the market has an excess supply of 1.5 because the quantity demanded, 9, is less than the quantity supplied, 10.5. With either excess demand or excess supply, market forces drive the price back to the equilibrium price of \$2.



We can determine the equilibrium quantity by substituting this equilibrium price, $p = \$2$, into either the supply or the demand equation:

$$\begin{aligned} Q_d &= Q_s \\ 12 - 2 &= 9 + (0.5 \times 2) \\ 10 &= 10. \end{aligned}$$

Thus, the equilibrium quantity is 10 million tons per year.

Forces That Drive a Market to Equilibrium

A market equilibrium is not just an abstract concept or a theoretical possibility.[8] We observe markets in equilibrium. The ability to buy as much as you want of a good at the market price is indirect evidence that a market is in equilibrium. You can usually buy as much as you want of milk, ballpoint pens, and many other goods.

Amazingly, a market equilibrium occurs without any explicit coordination between consumers and firms. In a competitive market such as that for agricultural goods, millions of consumers and thousands of firms make their buying and selling decisions independently. Yet, each firm can sell as much as it wants, and each consumer can buy as much as he or she wants. It is as though an unseen market force, like an *invisible hand*, directs people to coordinate their activities to achieve market equilibrium.

What really causes the market to be in equilibrium? If the price were not at the equilibrium level, consumers or firms would have an incentive to change their behavior in a way that would drive the price to the equilibrium level.[9]

If the price were initially lower than the equilibrium price, consumers would want to buy more than suppliers would want to sell. If the price of coffee were \$1 in Figure 2.6, consumers would demand $12 - 1 = 11$ million tons per year, but firms would be willing to supply only $9 + (0.5 \times 1) = 9.5$ million tons. At this price, the market would be in *disequilibrium*, meaning that the quantity demanded would not equal the quantity supplied. The market would have **excess demand**—the amount by which the quantity demanded exceeds the quantity supplied at a specified price—of $11 - 9.5 = 1.5$ million tons per year at a price of \$1 per lb.

Some consumers would be lucky enough to be able to buy coffee at \$1. Other consumers would not find anyone willing to sell them coffee at that price. What could they do? Some frustrated consumers might offer to pay suppliers more than \$1. Alternatively, suppliers, noticing these disappointed consumers, might raise their prices. Such actions by consumers and producers would cause the market price to rise. At higher prices, the quantity that firms want to supply increases and the quantity that consumers want to buy decreases. The upward pressure on the price would continue until it reached the equilibrium price, \$2, where the market has no excess demand.

If, instead, the price were initially above the equilibrium level, suppliers would want to sell more than consumers would want to buy. For example, at a price of coffee of \$3, suppliers would want to sell 10.5 million tons per year but consumers

[8]**MyLab Economics** has games (called *experiments*) for your course. These online games allow you to play against the computer. The *Market Experiment* illustrates the operation of the supply-and-demand model, allowing you to participate in a simulated market. To play, go to **MyLab Economics** Multimedia Library, Single Player Experiment, and set the Chapter field to "All Chapters."

[9]Our model of competitive market equilibrium, which occurs at a point in time, does not formally explain how dynamic adjustments occur. The following explanation, though plausible, is just one of a number of possible dynamic adjustment stories that economists have modeled.

would want to buy only 9 million, as the figure shows. Thus, at a price of \$3, the market would be in disequilibrium. The market would have **excess supply**—the amount by which the quantity supplied is greater than the quantity demanded at a specified price—of $10.5 - 9 = 1.5$ million tons at a price of \$3. Not all firms could sell as much as they wanted. Rather than incur storage costs (and possibly have their unsold coffee spoil), firms would lower the price to attract additional customers. As long as the price remained above the equilibrium price, some firms would have unsold coffee and would want to lower the price further. The price would fall until it reached the equilibrium level, \$2, without excess supply and hence no pressure to lower the price further.[10]

In summary, at any price other than the equilibrium price, either consumers or suppliers would be unable to trade as much as they want. These disappointed people would act to change the price, driving the price to the equilibrium level. The equilibrium price is called the *market clearing price* because it removes from the market all frustrated buyers and sellers: The market has no excess demand or excess supply at the market clearing price.

2.4 Shocking the Equilibrium: Comparative Statics

If the variables we hold constant in the demand and supply functions do not change, an equilibrium would persist indefinitely because none of the participants in the market would apply pressure to change the price. However, the equilibrium changes if a shock occurs so that one of the variables we were holding constant changes, causing a shift in either the demand curve or the supply curve.

Well, there goes the price of lobsters!

Comparative statics is the method economists use to analyze how variables controlled by consumers and firms—here, price and quantity—react to a change in *environmental variables* (also called *exogenous variables*) that they do not control. Such environmental variables include the prices of substitutes, the prices of complements, the income level of consumers, and the prices of inputs. The term *comparative statics* literally refers to comparing a *static* equilibrium—an equilibrium at a point in time from before the change—to a static equilibrium after the change. (In contrast, economists may examine a dynamic model, in which the dynamic equilibrium adjusts over time.)

[10]Not all markets reach equilibrium through the independent actions of many buyers or sellers. In institutionalized or formal markets, such as the Chicago Mercantile Exchange—where agricultural commodities, financial instruments, energy, and metals are traded—buyers and sellers meet at a single location (or on a single website). In these markets, certain individuals or firms, sometimes referred to as *market makers*, act to adjust the price and bring the market into equilibrium very quickly.

Comparative Statics with Discrete (Large) Changes

We can determine the comparative statics properties of an equilibrium by examining the effects of a discrete (relatively large) change in one environmental variable. We can do so by solving for the before- and after-equilibria and comparing them using mathematics or a graph. We illustrate this approach using our beloved coffee example. Suppose all the environmental variables remain constant except the price of cocoa, which increases by $3 per lb.

Because the price of cocoa is not an environmental variable in the demand function, the demand curve does not shift. However, as we saw in Figure 2.4, the increase in the price of cocoa causes the coffee supply curve to shift 0.6 units to the left from S^1 to S^2 at every possible price of coffee.

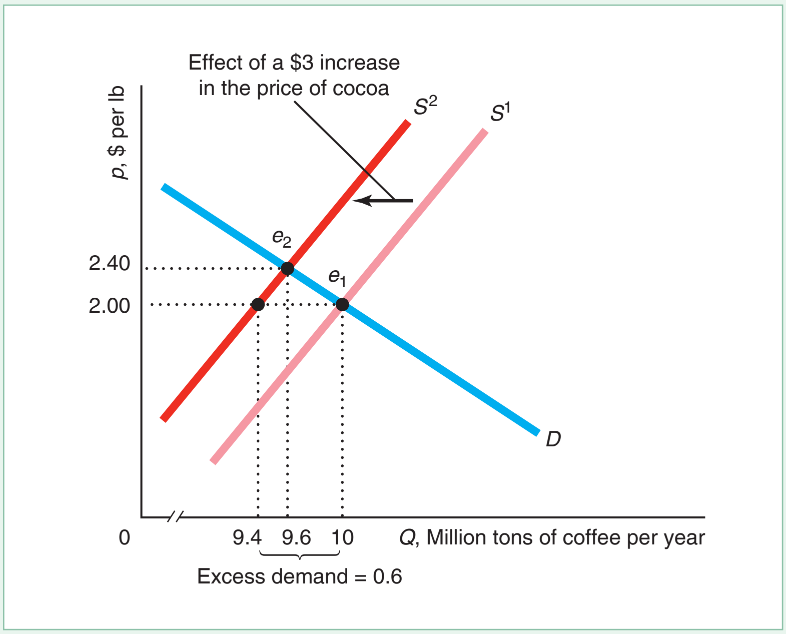
Figure 2.7 reproduces this shift of the supply curve and adds the original demand curve. At the original equilibrium price of coffee, $2, consumers still want to buy 10 million tons, but suppliers are now willing to supply only 9.4 million tons at that price, so the market has an excess demand of $10 - 9.4 = 0.6$. Market pressure forces the coffee price upward until it reaches the new equilibrium, e_2.

At e_2, the new equilibrium price is $2.40, and the new equilibrium quantity is 9.6 million tons. Thus, the increase in the price of cocoa causes the equilibrium price of coffee to rise by 40¢ per lb, and the equilibrium quantity to fall by 0.4 million tons. Here the increase in the price of cocoa causes a *shift of the supply curve* and a *movement along the demand curve*.

We can derive the same result by using equations to solve for the equilibrium before and after the discrete change in the price of cocoa and by comparing the two equations. We have already solved for the original equilibrium, e_1, by setting the quantity in the demand function Equation 2.3 equal to the quantity in the supply function Equation 2.7.

Figure 2.7 The Equilibrium Effect of a Shift of the Supply Curve

A $3 per lb increase in the price of cocoa causes some producers to shift from coffee production to cocoa production, reducing the quantity of coffee supplied at every price. The supply curve shifts to the left from S^1 to S^2, driving the market equilibrium from e_1 to e_2, where the new equilibrium price is $2.40.



We obtain the new equilibrium, e_2, by equating the quantity in the demand function Equation 2.3 to that of the new supply function, with the \$3 higher cocoa price, Equation 2.8:

$$12 - p = 8.4 + 0.5p.$$

Solving this expression, we find that the new equilibrium price is $p_2 = \$2.40$. Substituting that price into either the demand or the supply function, we learn that the new equilibrium quantity is $Q_2 = 9.6$, as Figure 2.7 shows. Thus, both methods show that an increase in the price of cocoa causes the equilibrium price to rise and the equilibrium quantity to fall.

APPLICATION

The Opioid Epidemic's Labor Market Effects

Opioids are drugs that act on the nervous system to relieve pain. They include heroin, fentanyl, and pain relievers that are available legally by prescription, such as oxycodone (OxyContin), hydrocodone (Vicodin), codeine, and morphine.

Although patients can safely use opioid pain relievers for a short period, many patients continue to use them for longer periods because these drugs produce euphoria in addition to pain relief. Unfortunately, continued use can cause dependence, and excessive use can cause death. Every day, 90 Americans die from opioid overdoses.

Opioid prescriptions per capita rose 350% nationwide between 1999 and 2015. The use and abuse of opioids are responsible for fewer people working due to premature deaths, an inability to pass a job drug test, or an unwillingness to work due to sedation and other effects of the drug.

Labor-force participation rate of men—the ratio of employed working-age men to all working-age men—was 3.2 percentage points lower during 2014–2016 than during 1999–2001. According to Krueger (2017), labor-force participation fell more in areas where doctors prescribe relatively more opioid pain medication. He calculated that 0.6 percentage points of the decline for men, a fifth of the total, was due to opioid prescriptions. Similarly, the study estimated that about one-quarter of the decline in women's labor-force participation was due to the growth in opioid prescriptions.

Thus, the opioid epidemic caused the labor supply curve to shift to the left, similar to Figure 2.7. As a result, the equilibrium quantity of labor fell and the equilibrium wage rose.

Comparative Statics with Small Changes

Alternatively, we can use calculus to determine the effect of a small change (as opposed to the discrete change we just used) in one environmental variable, holding the other such variables constant. Until now, we have used calculus to examine how an argument of a demand function affects the quantity demanded or how an argument of a supply function affects the quantity supplied. Now, however, we want to know how an environmental variable affects the equilibrium price and quantity that are determined by the intersection of the supply and demand curves.

Our first step is to characterize the equilibrium values as functions of the relevant environmental variables. Suppose that we hold constant all the environmental variables that affect demand so that the demand function is

$$Q = D(p). \tag{2.9}$$

One environmental variable, a, in the supply function changes, which causes the supply curve to shift. We write the supply function as

$$Q = S(p, a). \tag{2.10}$$

As before, we determine the equilibrium price by equating the quantities, Q, in Equations 2.9 and 2.10:

$$D(p) = S(p, a). \tag{2.11}$$

Equation 2.11 is an example of an *identity*. As a changes, p changes, so that this equation continues to hold—the market remains in equilibrium. Thus, based on this equation, we can write the equilibrium price as an implicit function of the environmental variable: $p = p(a)$. That is, we can write the equilibrium condition in Equation 2.11 as

$$D(p(a)) = S(p(a), a). \tag{2.12}$$

We can characterize how the equilibrium price changes with a by differentiating the equilibrium condition Equation 2.12 with respect to a using the chain rule at the original equilibrium,[11]

$$\frac{\mathrm{d}D(p(a))}{\mathrm{d}p}\frac{\mathrm{d}p}{\mathrm{d}a} = \frac{\partial S(p(a), a)}{\partial p}\frac{\mathrm{d}p}{\mathrm{d}a} + \frac{\partial S(p(a), a)}{\partial a}. \tag{2.13}$$

Using algebra, we can rearrange Equation 2.13 as

$$\frac{\mathrm{d}p}{\mathrm{d}a} = \frac{\dfrac{\partial S}{\partial a}}{\dfrac{\mathrm{d}D}{\mathrm{d}p} - \dfrac{\partial S}{\partial p}}, \tag{2.14}$$

where we suppress the arguments of the functions for notational simplicity. Equation 2.14 shows the derivative of $p(a)$ with respect to a.

We know that $\mathrm{d}D/\mathrm{d}p < 0$ because of the Law of Demand. If the supply curve is upward sloping, then $\partial S/\partial p$ is positive, so the denominator of Equation 2.14, $\mathrm{d}D/\mathrm{d}p - \partial S/\partial p$, is negative. Thus, $\mathrm{d}p/\mathrm{d}a$ has the opposite sign as the numerator of Equation 2.14. If $\partial S/\partial a$ is negative, then $\mathrm{d}p/\mathrm{d}a$ is positive: As a increases, the equilibrium price rises. If $\partial S/\partial a$ is positive, an increase in a causes the equilibrium price to fall.

By using either the demand function or the supply function, we can use this result concerning the effect of a on the equilibrium price to determine the effect of a on the equilibrium quantity. For example, we can rewrite the demand function Equation 2.9 as

$$Q = D(p(a)). \tag{2.15}$$

Differentiating the demand function Equation 2.15 with respect to a using the chain rule, we find that

$$\frac{\mathrm{d}Q}{\mathrm{d}a} = \frac{\mathrm{d}D}{\mathrm{d}p}\frac{\mathrm{d}p}{\mathrm{d}a}. \tag{2.16}$$

Because $\mathrm{d}D/\mathrm{d}p < 0$ by the Law of Demand, the sign of $\mathrm{d}Q/\mathrm{d}a$ is the opposite of that of $\mathrm{d}p/\mathrm{d}a$. That is, as a increases, the equilibrium price moves in the opposite direction of the equilibrium quantity. In Solved Problem 2.1, we use the coffee example to illustrate this type of analysis.

---

[11]The chain rule is a formula for the derivative of the composite of two functions, such as $f(g(x))$. According to this rule, $\mathrm{d}f/\mathrm{d}x = (\mathrm{d}f/\mathrm{d}g)(\mathrm{d}g/\mathrm{d}x)$. See the Calculus Appendix at the end of the book.

SOLVED PROBLEM 2.1

MyLab Economics Solved Problem

How do the equilibrium price and quantity of coffee vary as the price of cocoa changes, holding the variables that affect demand constant at their typical values? Answer this comparative statics question using calculus. (*Hint*: This problem has the same form as the more general one we just analyzed. In the cocoa market, the environmental variable that shifts supply, a, is p_c.)

Answer

1. *Solve for the equilibrium coffee price in terms of the cocoa price.* To obtain an expression for the equilibrium similar to Equation 2.14, we equate the right sides of the demand function in Equation 2.3 and the supply function Equation 2.6 to obtain

$$12 - p = 9.6 + 0.5p - 0.2p_c, \text{ or}$$
$$p = (2.4/1.5) + (0.2/1.5)p_c = 1.6 + 0.133\dot{3}p_c. \tag{2.17}$$

(As a check, when p_c equals its original value, \$3, in Equation 2.17, the equilibrium coffee price is $p = \$2$, which is consistent with our earlier calculations.)

2. *Use this equilibrium price equation to show how the equilibrium price changes as the price of cocoa changes.* Differentiating the equilibrium price Equation 2.17 with respect to p_c gives an expression of the form of Equation 2.16:

$$\frac{dp}{dp_c} = 0.133\dot{3}. \tag{2.18}$$

Because this condition holds for any value of p_c (the derivative does not vary with p_c), it also holds for large changes in the price of cocoa. For example, as the cocoa price increases by \$3, the equilibrium cocoa price increases by $0.133\dot{3} \times \$3 = \$0.40$, as Figure 2.7 shows.

3. *Write the coffee demand function as in Equation 2.15, and then differentiate it with respect to the cocoa price to show how the equilibrium quantity of coffee varies with the cocoa price.* From the coffee demand function, Equation 2.3, we can write the quantity demanded as

$$Q = D(p(p_c)) = 12 - p(p_c),$$

where $p(p_c)$ is given by Equation 2.17. That is,

$$Q = D(p(p_c)) = 12 - (1.6 + 0.133\dot{3}p_c) = 10.4 - 0.133\dot{3}p_c.$$

Differentiating this expression with respect to p_c using the chain rule, we obtain

$$\frac{dQ}{dp_c} = \frac{dD}{dp}\frac{dp}{dp_c} = -1 \times 0.133\dot{3} = -0.133\dot{3}, \tag{2.19}$$

where dp/dp_c is given by Equation 2.18. That is, as the price of cocoa increases by \$1, the equilibrium quantity of coffee falls by $0.133\dot{3}$ tons per year. Because the derivative in Equation 2.19 does not vary with p_c, it holds for large changes. Thus, if the price of cocoa increases by \$3, then the equilibrium quantity falls by $0.133\dot{3} \times 3 = 0.4$ million tons per year, as Figure 2.7 shows.

Why the Shapes of Demand and Supply Curves Matter

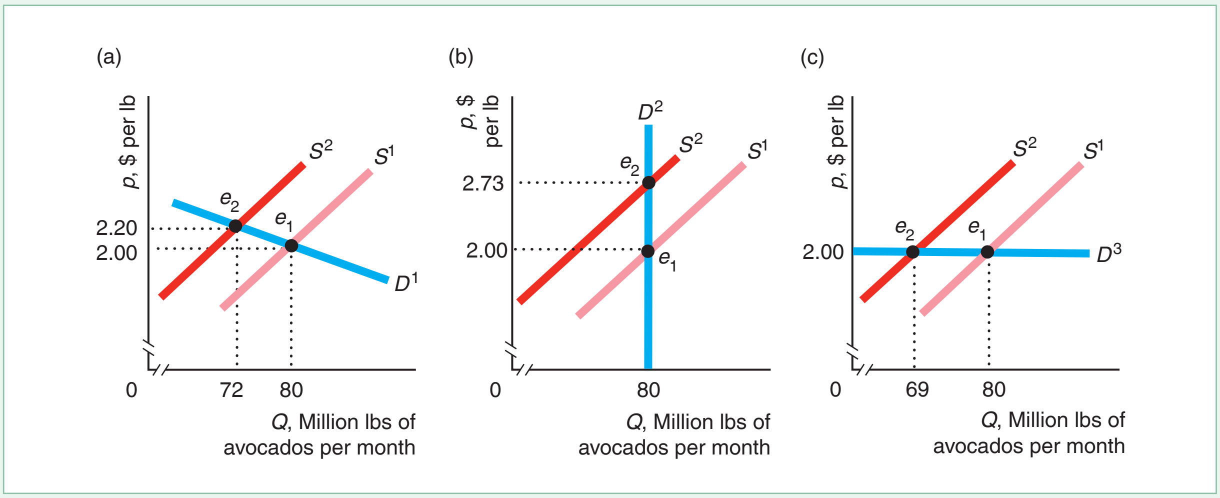
The shapes and positions of the demand and supply curves determine how much a shock affects the equilibrium price and quantity. We illustrate the importance of the shape of the demand curve using the estimated avocado demand and supply curves.[12] We start by determining what happens if the price of fertilizer (an input to the production of avocados) increases by 55¢ per lb, which causes the avocado supply curve to shift to the left from S^1 to S^2 in panel a of Figure 2.8. The *shift of the supply curve* causes a *movement along the estimated demand curve*, D^1. The equilibrium quantity falls from 80 to 72 million lb per month, and the equilibrium price rises 20¢ from $2.00 to $2.20 per lb, hurting consumers.

A supply shock would have different effects if the demand curve had a different shape. Suppose that the quantity demanded were not sensitive to a change in the price, so that a change in the price does not affect the amount demanded, as the vertical demand curve D^2 in panel b shows. A 55¢ increase in the fertilizer price again shifts the supply curve from S^1 to S^2. However, with the vertical demand curve, the equilibrium quantity does not change, but the price consumers pay rises by more, going from $2 to $2.73. Thus, the amount consumers spend rises by more when the demand curve is vertical instead of downward sloping.

Now suppose that consumers are extremely sensitive to price changes, as the horizontal demand curve, D^3, in panel c shows. Consumers will buy virtually

Figure 2.8 The Effects of a Shift of the Supply Curve Depend on the Shape of the Demand Curve

A 55¢ increase in the price of fertilizer shifts the avocado supply curve to the left from S^1 to S^2. (a) Given the actual, estimated downward-sloping linear demand curve, D^1, the equilibrium price rises from $2.00 to $2.20 and the equilibrium quantity falls from 80 to 72. (b) If the demand curve were vertical, D^2, the supply shock would cause price to rise to $2.73 while quantity would remain unchanged. (c) If the demand curve were horizontal, D^3, the supply shock would not affect price but would cause quantity to fall to 69.



[12]The supply and demand curves are based on estimates from Carman (2006), which we updated with more recent data from the California Avocado Commission and supplemented with information from other sources.

unlimited quantities of avocados at \$2 per lb (or less). However, if the price rises even slightly, they stop buying avocados altogether. With a horizontal demand curve, an increase in the price of avocados has *no* effect on the price consumers pay; however, the equilibrium quantity drops substantially from 80 to 69 million lb per month. Thus, how much the equilibrium quantity falls and how much the equilibrium price of avocados rises when the fertilizer price increases depend on the shape of the demand curve.

2.5 Elasticities

It is convenient to be able to summarize the responsiveness of one variable to a change in another variable using a summary statistic. In our last example, we wanted to know whether an increase in the price of a product causes a large or a small change in the quantity demanded (that is, whether the demand curve is relatively vertical or relatively horizontal at the current price). We can use summary statistics of the responsiveness of the quantity demanded and the quantity supplied to determine comparative statics properties of the equilibrium. Often, we have reasonable estimates of these summary statistics and can use them to predict what will happen to the equilibrium in a market—that is, to make comparative statics predictions. Later in this chapter, we will examine how the government can use these summary measures to predict how a tax on a product will affect the equilibrium price and quantity, and hence firms' revenues and the government's tax receipts.

Suppose that a variable z (for example, the quantity demanded or the quantity supplied) is a function of a variable x (say, the price of z) and possibly other variables such as y. We write this function as $z = f(x, y)$. For example, f could be the demand function, where z is the quantity demanded, x is the price, and y is income. We want a summary statistic that describes how much z changes as x changes, holding y constant. An **elasticity** is the percentage change in one variable (here, z) in response to a given percentage change in another variable (here, x), holding other relevant variables (here, y) constant. The elasticity, E, of z with respect to x is

$$E = \frac{\text{percentage change in } z}{\text{percentage change in } x} = \frac{\Delta z/z}{\Delta x/x} = \frac{\partial z}{\partial x}\frac{x}{z}, \tag{2.20}$$

where Δz is the change in z, so $\Delta z/z$ is the percentage change in z. If z changes by 3% when x changes by 1%, then the elasticity E is 3. Thus, the elasticity is a pure number (it has no units of measure).[13] As Δx goes to zero, $\Delta z/\Delta x$ goes to the partial derivative $\partial z/\partial x$. Economists usually calculate elasticities at this limit—that is, for infinitesimal changes in x.

Demand Elasticity

The **price elasticity of demand** (or simply the *demand elasticity* or *elasticity of demand*) is the percentage change in the quantity demanded, Q, in response to a given percentage change in the price, p, at a particular point on the demand curve.

[13]Economists use the elasticity rather than the slope, $\partial z/\partial x$, as a summary statistic because the elasticity is a pure number, whereas the slope depends on the units of measurement. For example, if x is a price measured in pennies and we switch to measuring price using dollars, the slope changes, but the elasticity remains unchanged.

The price elasticity of demand (represented by ε, the Greek letter epsilon), a special case of Equation 2.20, is

$$\varepsilon = \frac{\text{percentage change in quantity demanded}}{\text{percentage change in price}} = \frac{\Delta Q/Q}{\Delta p/p} = \frac{\partial Q}{\partial p}\frac{p}{Q}, \tag{2.21}$$

where $\partial Q/\partial p$ is the partial derivative of the demand function with respect to p (that is, holding constant other variables that affect the quantity demanded).

The elasticity of demand concisely answers the question "How much does the quantity demanded of a product fall in response to a 1% increase in its price?" A 1% increase in price leads to an ε% change in the quantity demanded. For example, Roberts and Schlenker (2013) estimated that the elasticity of corn is −0.3. A 1% increase in the price of corn leads to a −0.3% fall in the quantity of corn demanded. Thus, a price increase causes a less than proportionate fall in the quantity of corn demanded.

We can use Equation 2.21 to calculate the elasticity of demand for a linear demand function that holds fixed other variables that affect demand:

$$Q = a - bp,$$

where a is the quantity demanded when the price is zero, $Q = a - (b \times 0) = a$, and $-b$ is the ratio of the fall in the quantity relative to the rise in price: the derivative $\mathrm{d}Q/\mathrm{d}p$. The elasticity of demand is

$$\varepsilon = \frac{\mathrm{d}Q}{\mathrm{d}p}\frac{p}{Q} = -b\frac{p}{Q}. \tag{2.22}$$

SOLVED PROBLEM 2.2

MyLab Economics Solved Problem

The estimated U.S. linear corn demand function is

$$Q = 15.6 - 0.5p, \tag{2.23}$$

where p is the price in dollars per bushel and Q is the quantity demanded in billion bushels per year.[14] What is the elasticity of demand at the point on the demand curve where the price is $p = \$7.20$ per bushel?

Answer

Substitute the slope coefficient b, the price, and the quantity in Equation 2.22. Equation 2.23 is a special case of the general linear demand function $Q = a - bp$, where $a = 15.6$ and $b = 0.5$. Evaluating Equation 2.23 at $p = \$7.20$, we find that the quantity demanded is $Q = 15.6 - (0.5 \times 7.20) = 12$ billion bushels per year. Substituting $b = 0.5$, $p = \$7.20$, and $Q = 12$ into Equation 2.22, we learn that the elasticity of demand at this point on the demand curve is

$$\varepsilon = -b\frac{p}{Q} = -0.5 \times \frac{7.20}{12} = -0.3.$$

The negative sign on the corn elasticity of demand illustrates the Law of Demand: Less quantity is demanded as the price rises.

[14]This demand curve is a linearized version of the estimated demand curve in Roberts and Schlenker (2013). I have rounded their estimated elasticities slightly for algebraic simplicity.

APPLICATION

The Demand Elasticities for Google Play and Apple Apps

As of the first quarter of 2018, the Apple App Store (iOS) had about 2.0 million apps (mobile applications for smartphones and tablets) and Google Play (Android) had 3.8 million. How price sensitive are consumers of apps? Are Apple aficionados more or less price sensitive than people who use Android devices?

Ghose and Han (2014) estimated the demand for an app in the Apple App Store is −2.0. That is, a 1% increase in price causes a 2% drop in the demand for an Apple app. Thus, demand is elastic in the Apple App Store.

The estimated demand elasticity for an app in Google Play is −3.7, which means an Android app has a nearly twice as elastic demand as does an Apple app. Therefore, Google Play consumers are more price sensitive than are Apple App consumers.

Elasticities Along the Demand Curve. The elasticity of demand varies along most demand curves. On downward-sloping linear demand curves (lines that are neither vertical nor horizontal), the higher the price, the more negative the elasticity of demand. Consequently, even though the slope of the linear demand curve is constant, the elasticity varies along the curve. A 1% increase in the price causes a larger percentage fall in the quantity demanded near the top (left) of the demand curve than near the bottom (right).

Where a linear demand curve hits the quantity axis ($p = 0$ and $Q = a$), the elasticity of demand is $\varepsilon = -b \times (0/a) = 0$, according to Equation 2.22. The linear coffee demand curve in Figure 2.9 illustrates this pattern. Where the price is zero, a 1% increase in price does not raise the price, so quantity demanded does not change. At a point where the elasticity of demand is zero, the demand curve is said to be *perfectly inelastic*. As a physical analogy, if you try to stretch an inelastic steel rod, the length does not change. The change in the price is the force pulling at demand; if the quantity demanded does not change in response to this force, the demand curve is perfectly inelastic.

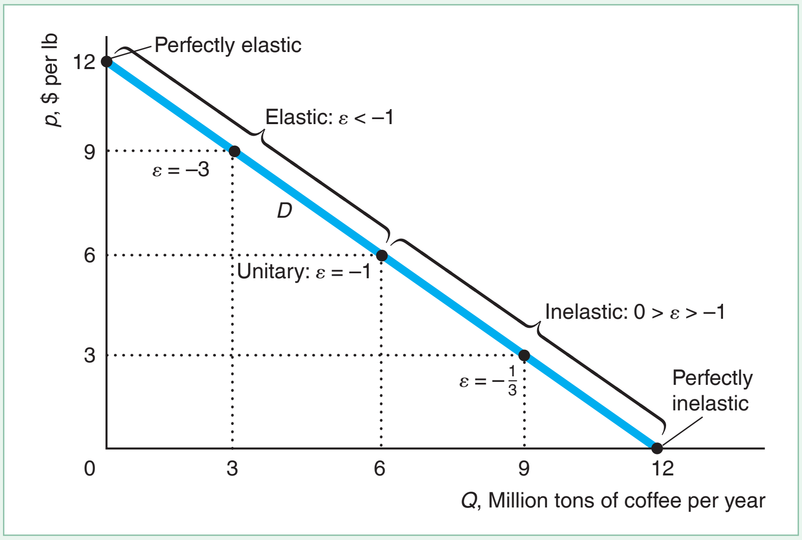
For quantities between the midpoint of the linear demand curve and the lower end, where $Q = a$, the demand elasticity lies between 0 and −1: $0 > \varepsilon > -1$. A point along the demand curve where the elasticity is between 0 and −1 is *inelastic* (but not perfectly inelastic): A 1% increase in price leads to a fall in quantity of less than 1%. For example, at $p = \$3$ and $Q = 9$, $\varepsilon = -\frac{1}{3}$, so a one percent increase in price causes quantity to fall by one-third of a percent. A physical analogy is a piece of rope that does not stretch much—is inelastic—when you pull on it: Changing price has relatively little effect on quantity.

At the midpoint of any linear demand curve, $p = a/(2b)$ and $Q = a/2$, so $\varepsilon = -bp/Q = -b[a/(2b)]/(a/2) = -1$.[15] Such an elasticity of demand is called a *unitary elasticity*.

[15]The linear demand curve hits the price axis at $p = a/b$ and the quantity axis at $p = 0$. The midpoint occurs at $p = (a/b - 0)/2 = a/(2b)$, where the quantity is $Q = a - b[a/(2b)] = a/2$.

Figure 2.9 The Elasticity of Demand Varies Along the Linear Coffee Demand Curve

With a linear demand curve, such as the coffee demand curve, the higher the price, the more elastic the demand curve (ε is larger in absolute value: It becomes a more negative number as we move up the demand curve). The demand curve is perfectly inelastic ($\varepsilon = 0$) where the demand curve hits the horizontal axis, is perfectly elastic where the demand curve hits the vertical axis, and has unitary elasticity at the midpoint of the demand curve.



At prices higher than at the midpoint of the demand curve, the elasticity of demand is less than negative one, $\varepsilon < -1$. In this range, the demand curve is called *elastic*: A 1% increase in price causes more than a 1% fall in quantity. A physical analogy is a rubber band that stretches substantially when you pull on it. Figure 2.9 shows that the coffee demand elasticity is -3 where $p = \$9$ and $Q = 3$: A 1% increase in price causes a 3% drop in the quantity demanded.

As the price rises, the elasticity gets more and more negative, approaching negative infinity. Where the demand curve hits the price axis, it is *perfectly elastic*.[16] At the price a/b where $Q = 0$, a 1% decrease in p causes the quantity demanded to become positive, which is an infinite increase in quantity.

The elasticity of demand varies along most demand curves, not just downward-sloping linear ones. However, along a special type of demand curve, called a *constant-elasticity demand curve*, the elasticity is the same at every point along the curve. Constant-elasticity demand curves all have the exponential form

$$Q = Ap^{\varepsilon}, \tag{2.24}$$

where A is a positive constant and ε, a negative constant, is the elasticity at every point along this demand curve. By taking natural logarithms of both sides of Equation 2.24, we can rewrite this exponential demand curve as a log-linear demand curve:

$$\ln Q = \ln A + \varepsilon \ln p. \tag{2.25}$$

For example, given the information in the Application "The Demand Elasticities for Google Play and Apple Apps," the estimated demand function for Apple apps

[16]The linear demand curve hits the price axis at $p = a/b$ and $Q = 0$, so the elasticity of demand is $-bp/0$. As the price approaches a/b, the elasticity approaches negative infinity, $-\infty$. An intuition for this result is provided by looking at a sequence where -1 divided by 0.1 is -10, -1 divided by 0.01 is -100, and so on. The smaller the number we divide by, the more negative the result, which goes to $-\infty$ in the limit.

(mobile applications) is $Q = 1.4p^{-2}$, where the quantity is in millions of apps. Here, $A = 1.4$, and $\varepsilon = -2$ is the constant-elasticity of demand. That is, the demand for Apple apps is elastic: $\varepsilon < -1$. We can equivalently write this demand function as $\ln Q = \ln 1.4 - 2 \ln p$.

Figure 2.10 shows several constant-elasticity demand curves with different elasticities. Except for the vertical and the horizontal demand curves, the curves are convex to the origin (bend away from the origin). The two extreme cases of these constant-elasticity demand curves are the vertical and the horizontal demand curves. Along the demand curve that is horizontal at p^* in Figure 2.10, the elasticity is infinite everywhere. It is also a special case of a linear demand curve with a zero slope ($b = 0$). Along this demand curve, people are willing to buy as much as firms sell at any price less than or equal to p^*. If the price increases even slightly above p^*, however, demand falls to zero. Thus, a small increase in price causes an infinite drop in the quantity demanded, which means that the demand curve is perfectly elastic.

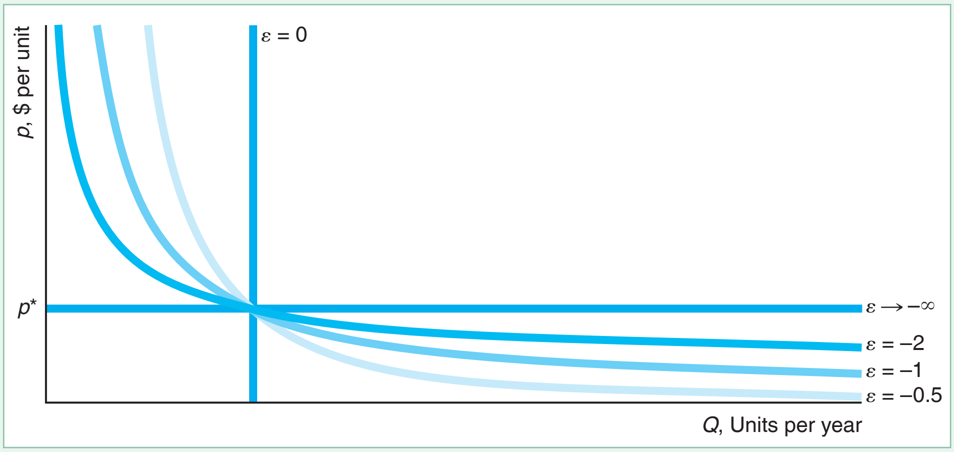
Why would a demand curve be horizontal? One reason is that consumers view one good as identical to another good and do not care which one they buy. Suppose that consumers view Washington State apples and Oregon apples as identical. They won't buy Washington apples if these apples sell for more than Oregon apples. Similarly, they won't buy Oregon apples if their price is higher than that of Washington apples. If the two prices are equal, consumers do not care which type of apple they buy. Thus, the demand curve for Oregon apples is horizontal at the price of Washington apples.

The other extreme case is the vertical demand curve, which is perfectly inelastic everywhere. Such a demand curve is also an extreme case of the linear demand curve with an infinite (vertical) slope. If the price goes up, the quantity demanded is unchanged, $dQ/dp = 0$, so the elasticity of demand must be zero: $\varepsilon = (dQ/dp)(p/Q) = 0 \times (p/Q) = 0$.

A demand curve is vertical for *essential goods*—goods that people feel they must have and will pay anything to get. Because Sydney has diabetes, her demand curve for insulin could be vertical at a day's dose, Q^*.[17]

Figure 2.10 Constant-Elasticity Demand Curves

These constant-elasticity demand curves, $Q = Ap$, vary with respect to their elasticities. Curves with negative, finite elasticities are convex to the origin. The vertical, constant-elasticity demand curve is perfectly inelastic, while the horizontal curve is perfectly elastic.



[17]More realistically, she may have a maximum price, p^*, that she can afford to pay. Thus, her demand curve is vertical at Q^* up to p^* and horizontal at p^* to the left of Q^*.

SOLVED PROBLEM 2.3

MyLab Economics Solved Problem

Show that the price elasticity of demand is a constant ε if the demand function is exponential, $Q = Ap^{\varepsilon}$, or, equivalently, log-linear, $\ln Q = \ln A + \varepsilon \ln p$.

Answer

1. *Differentiate the exponential demand curve with respect to price to determine* $\mathrm{d}Q/\mathrm{d}p$*, and substitute that expression into the definition of the elasticity of demand.* Differentiating the demand curve $Q = Ap^{\varepsilon}$, we find that $\mathrm{d}Q/\mathrm{d}p = \varepsilon Ap^{\varepsilon - 1}$. Substituting that expression into the elasticity definition, we learn that the elasticity is

$$\frac{\mathrm{d}Q}{\mathrm{d}p}\frac{p}{Q} = \varepsilon Ap^{\varepsilon-1}\frac{p}{Q} = \varepsilon Ap^{\varepsilon-1}\frac{p}{Ap^{\varepsilon}} = \varepsilon.$$

Because the elasticity is a constant that does not depend on the particular value of p, it is the same at every point along the demand curve.

2. *Differentiate the log-linear demand curve to determine* $\mathrm{d}Q/\mathrm{d}p$*, and substitute that expression into the definition of the elasticity of demand.* Differentiating the log-linear demand curve, $\ln Q = \ln A + \varepsilon \ln p$, with respect to p, we find that $\mathrm{d}(\ln Q)/\mathrm{d}p = (\mathrm{d}Q/\mathrm{d}p)/Q = \varepsilon/p$. Multiplying this Equation by p, we again discover that the elasticity is constant:

$$\frac{\mathrm{d}Q}{\mathrm{d}p}\frac{p}{Q} = \varepsilon\frac{Q}{p}\frac{p}{Q} = \varepsilon.$$

Other Types of Demand Elasticities. We refer to the price elasticity of demand as *the* elasticity of demand. However, other types of demand elasticities show how the quantity demanded changes in response to changes in variables other than price that affect the quantity demanded. Two such demand elasticities are the income elasticity of demand and the cross-price elasticity of demand.

As people's incomes increase, their demand curves for products shift. If a demand curve shifts to the right, consumers demand a larger quantity at any given price. If instead the demand curve shifts to the left, consumers demand a smaller quantity at any given price.

We can measure how sensitive the quantity demanded at a given price is to income by using the **income elasticity of demand** (or *income elasticity*), which is the percentage change in the quantity demanded in response to a given percentage change in income, Y. The income elasticity of demand is

$$\xi = \frac{\text{percentage change in quantity demanded}}{\text{percentage change in income}} = \frac{\Delta Q/Q}{\Delta Y/Y} = \frac{\partial Q}{\partial Y}\frac{Y}{Q},$$

where ξ is the Greek letter xi. If the quantity demanded increases as income rises, the income elasticity of demand is positive. If the quantity demanded does not change as income rises, the income elasticity is zero. Finally, if the quantity demanded falls as income rises, the income elasticity is negative.

By partially differentiating the coffee demand function, Equation 2.2, $Q = 8.5 - p - 0.3p_s + 0.1Y$, with respect to Y, we find that $\partial Q/\partial Y = 0.1$, so the coffee income elasticity of demand is $\xi = 0.1Y/Q$. At our original equilibrium, quantity is $Q = 10$ and income is $Y = 35$ ($35,000), so the income elasticity is $\xi = 0.1 \times (35/10) = 0.35$. The positive income elasticity shows that an increase in income causes the coffee demand curve to shift to the right. Holding the price of coffee constant at \$2 per lb, a 1% increase in income causes the demand curve for coffee to shift to the right by 0.35%.

Income elasticities play an important role in our analysis of consumer behavior in Chapter 5. Typically, goods that consumers view as necessities, such as food, have income elasticities near zero. The estimated income elasticity for wireless access is 0.42 (Kridel, 2014). Goods that they consider luxuries generally have income elasticities greater than one.

The **cross-price elasticity of demand** is the percentage change in the quantity demanded in response to a given percentage change in the price of another good, p_o. The cross-price elasticity is

$$\frac{\text{percentage change in quantity demanded}}{\text{percentage change in price of another good}} = \frac{\Delta Q/Q}{\Delta p_o/p_o} = \frac{\partial Q}{\partial p_o}\frac{p_o}{Q}.$$

If the cross-price elasticity is positive, the goods are *substitutes*. As the price of the second good increases, the demand curve for the first good shifts to the right, so people buy more of the first good at any given price.

If the cross-price elasticity is negative, the goods are *complements*.[18] An increase in the price of the second good causes the demand curve for the first good to shift leftward, so people buy less of the first good at any given price.

For example, coffee and sugar are complements: Many people put sugar in their coffee. By partially differentiating the coffee demand function, Equation 2.2, $Q = 8.5 - p - 0.3p_s + 0.1Y$, with respect to the price of sugar, p_s, we find that $\partial Q/\partial p_s = -0.3$. That is, an increase in the price of sugar causes the quantity demanded of coffee to fall, holding the price of coffee and income constant. The cross-price elasticity between the price of sugar and the quantity demanded of coffee is $(\partial Q/\partial p_s)(p_s/Q) = -0.3p_s/Q$. At the original equilibrium, where $Q = 10$ million tons per year and $p_s = \$0.20$ per lb, the cross-price elasticity is $-0.3 \times (0.20/10) = -0.006$. As the price of sugar rises by 1%, the quantity of coffee demanded falls by only 0.006%.

Taking account of cross-price elasticities is important in making business and policy decisions. For example, General Motors wants to know how much a change in the price of a Toyota affects the demand for its Chevy. Society wants to know if taxing soft drinks will substantially increase the demand for milk.

Supply Elasticity

Just as we can use the elasticity of demand to summarize information about the responsiveness of the quantity demanded to price or other variables, we can use the elasticity of supply to summarize how responsive the quantity supplied of a product is to price changes or other variables. The **price elasticity of supply** (or *supply elasticity*) is the percentage change in the quantity supplied in response to a given percentage change in the price. The price elasticity of supply (η, the Greek letter eta) is

$$\eta = \frac{\text{percentage change in quantity supplied}}{\text{percentage change in price}} = \frac{\Delta Q/Q}{\Delta p/p} = \frac{\partial Q}{\partial p}\frac{p}{Q}, \tag{2.26}$$

where Q is the *quantity supplied*. If $\eta = 2$, a 1% increase in price leads to a 2% increase in the quantity supplied.

The definition of the price elasticity of supply, Equation 2.26, is very similar to the definition of the price elasticity of demand, Equation 2.21. The key distinction is

---

[18]*Jargon alert*: Graduate-level textbooks generally call these goods *gross complements* and the goods in the previous example *gross substitutes*.

that the elasticity of supply describes the movement along the *supply* curve as price changes, whereas the elasticity of demand describes the movement along the *demand* curve as price changes. That is, in the numerator, supply elasticity depends on the percentage change in the *quantity supplied*, whereas demand elasticity depends on the percentage change in the *quantity demanded*.

If the supply curve is upward sloping, $\partial p/\partial Q > 0$, the supply elasticity is positive: $\eta > 0$. If the supply curve slopes downward, the supply elasticity is negative: $\eta < 0$.

At a point on a supply curve where the elasticity of supply is $\eta = 0$, we say that the supply curve is *perfectly inelastic*: The supply does not change as the price rises. If $0 < \eta < 1$, the supply curve is *inelastic* (but not perfectly inelastic): A 1% increase in the price causes a less than 1% rise in the quantity supplied. If $\eta = 1$, the supply curve is *unitary elastic*. If $\eta > 1$, the supply curve is *elastic*. If η is infinite, the supply curve is *perfectly elastic*.

To illustrate the supply elasticity, we use the estimated linear U.S. corn supply function (based on Roberts and Schlenker, 2013)

$$Q = 10.2 + 0.25p, \tag{2.27}$$

where Q is the quantity of corn supplied in billion bushels per year and p is the price of corn in dollars per bushel. Differentiating Equation 2.27, we find that $\mathrm{d}Q/\mathrm{d}p = 0.25$. At the point on the supply curve where $p = \$7.20$ and $Q = 12$, the elasticity of supply is

$$\eta = \frac{\mathrm{d}Q}{\mathrm{d}p}\frac{p}{Q} = 0.25 \times \frac{7.20}{12} = 0.15.$$

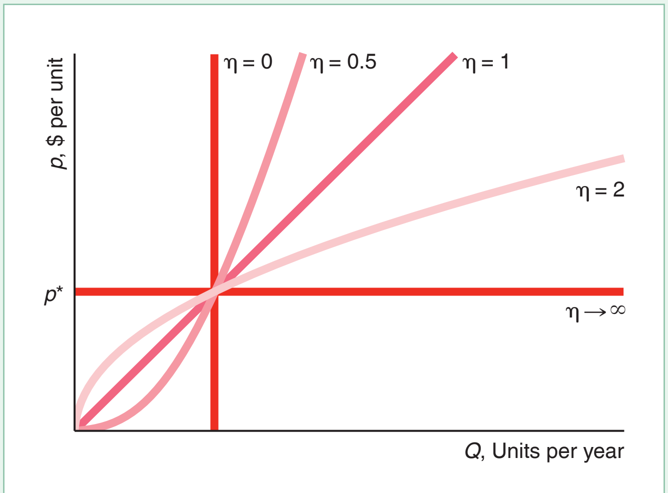
At this point on the supply curve, a 1% increase in the price of corn leads to a 0.15% rise in the quantity of corn supplied. That is, the supply curve is inelastic at this point.

The elasticity of supply may vary along a supply curve. For example, because the corn elasticity of supply is $\eta = 0.25p/Q$, as the ratio p/Q rises, the supply elasticity rises.

The supply elasticity does not vary along constant-elasticity supply functions, which are exponential or (equivalently) log-linear: $Q = Bp^{\eta}$ or $\ln Q = \ln B + \eta \ln p$. If η is a positive, finite number, the constant-elasticity supply curve starts at the origin, as Figure 2.11 shows. Two extreme examples of both constant-elasticity of supply curves and linear supply curves are the vertical supply curve and the horizontal supply curve.

Figure 2.11 Constant-Elasticity Supply Curves

Constant-elasticity supply curves, $Q = Bp^{\eta}$, with positive, finite elasticities, start at the origin. They are concave to the horizontal axis if $1 < \eta < \infty$ and convex if $0 < \eta < 1$. The unitary-elasticity supply curve is a straight line through the origin. The vertical constant-elasticity supply curve is perfectly inelastic, while the horizontal curve is perfectly elastic.



A supply curve that is vertical at a quantity, Q^*, is perfectly inelastic. No matter what the price is, firms supply Q^*. An example of inelastic supply is a perishable item such as already-picked fresh fruit. Unsold perishable goods quickly become worthless. Thus, the seller will accept any market price for the good.

A supply curve that is horizontal at a price, p^*, is perfectly elastic. Firms supply as much as the market wants—a potentially unlimited amount—if the price is p^* or above. Firms supply nothing at a price below p^*, which does not cover their cost of production.

SOLVED PROBLEM 2.4

MyLab Economics Solved Problem

Show that the price elasticity of supply is 1 for a linear supply curve that starts at the origin.

Answer

1. *Write the formula for a linear supply curve that starts at the origin.* In general, a linear supply function is $Q = A + Bp$. If $p = 0$, then $Q = A$. For a linear supply curve to start at the origin ($p = 0$, $Q = 0$), A must be zero. Thus, the supply function is $Q = Bp$. For firms to supply positive quantities at a positive price, we need $B > 0$.
2. *Calculate the supply elasticity based on this linear function by using the definition.* The supply elasticity is $\eta = (\mathrm{d}Q/\mathrm{d}p)(p/Q) = B(p/Q) = B(p/[Bp]) = 1$, regardless of the slope of the line, B.

Comment: This supply function is a special case of the constant-elasticity supply function where $Q = Bp^{\eta} = Bp^1$, so $\eta = 1$.

Long Run Versus Short Run

Typically, short-run demand or supply elasticities differ substantially from long-run elasticities. The duration of the short run depends on the planning horizon—how long it takes consumers or firms to adjust for a particular good.

Demand Elasticities over Time. Two factors that determine whether short-run demand elasticities are larger or smaller than long-run elasticities are the ease of substitution and storage opportunities. Often one can substitute between products in the long run but not in the short run.

The shape of a demand curve depends on the period under consideration. Often consumers substitute between products in the long run but not in the short run. The price of U.S. gasoline in May 2018 was nearly one-third higher than in the previous year. However, most consumers did not change their consumption demand very much in the short run. Someone who drives 27 miles to and from work every day in a Ford Explorer did not suddenly start using less gasoline. However, if gas prices were to remain high in the long run, people would reduce their consumption of gasoline. Many people would buy smaller, more fuel-efficient cars, some people would take jobs closer to home, and some would even move closer to their work or closer to convenient public transportation.

Liddle (2012) estimated the gasoline demand elasticities across many countries and found that the short-run elasticity for gasoline was −0.16 and the long-run elasticity was −0.43. Thus, a 1% increase in price lowers the quantity demanded by only 0.16% in the short run but by more than twice as much, 0.43%, in the long run.

In contrast, the short-run demand elasticity for goods that can be stored easily may be more elastic than the long-run ones. Prince (2008) found that the demand for computers was more elastic in the short run (−2.74) than in the long run (−2.17). His explanation was that consumers worry about being locked-in with an older technology in the short run so that they were more sensitive to price in the short run.

Supply Elasticities over Time. Short-run supply curve elasticities may differ from long-run elasticities. If a manufacturing firm wants to increase production in the short run, it can do so by hiring workers to use its machines around the clock. However, the fixed size of its manufacturing plant and fixed number of machines in the plant limit how much it can expand its output.

In the long run, however, the firm can build another plant and buy or build more equipment. Thus, we would expect a firm's long-run supply elasticity to be greater than it is in the short run.

Similarly, the market supply elasticity may be greater in the long run than in the short run. For example, Clemens and Gottlieb (2014) estimated that the health care supply elasticity is twice as elastic in the long run (1.4) as in the short run (0.7).

APPLICATION

Oil Drilling in the Arctic National Wildlife Refuge

We can use information about supply and demand elasticities to answer an important public policy question: Would selling oil from the Arctic National Wildlife Refuge (ANWR) substantially affect the price of oil? ANWR, established in 1960, is the largest of Alaska's 16 national wildlife refuges, covers 20 million acres, and is believed to contain large deposits of petroleum (about the amount consumed in the United States in a year). For decades, a debate has raged over whether U.S. citizens, who own the refuge, should keep it pristine or permit oil drilling.[19]

The Obama administration sided with environmentalists who stress that drilling would harm the wildlife refuge and pollute the environment. On the other side, the Trump administration and drilling proponents argue that extracting this oil would substantially reduce the price of petroleum as well as decrease U.S. dependence on foreign oil. Recent large fluctuations in the price of gasoline and unrest in the Middle East have heightened this intense debate.

The effect of selling ANWR oil on the world price of oil is a key element of this dispute. We can combine oil production information with supply and demand elasticities to make a "back of the envelope" estimate of the price effects. Baumeister and Peersman (2013) estimated that the short-run elasticity of demand, ε, for oil is about -0.25 and the long-run supply elasticity, η, is about 0.25.

Analysts dispute how much ANWR oil could be produced. The U.S. Department of Energy's Energy Information Service predicts that production from ANWR would average about 800,000 barrels per day. That production would be less than 1% of the worldwide oil production, which is predicted to be about 100 million barrels per day in 2018.

A report by the Department of Energy predicted that drilling in the refuge could lower the price of oil by about 1%. In Solved Problem 2.5, we make our own calculation of the price effect of drilling in ANWR. Here and in many of the solved problems, you are asked to determine how a change in a variable or policy (such as permitting ANWR drilling) affects one or more variables (such as the world equilibrium price of oil).

[19] I am grateful to Robert Whaples, who wrote an earlier version of this analysis. In the following discussion, we assume for simplicity that the oil market is competitive, and use current values of price and quantities even though drilling in the Arctic National Wildlife Refuge could not take place for at least a decade from when the decision to drill occurs.

SOLVED PROBLEM 2.5

MyLab Economics Solved Problem

What would be the effect of ANWR production on the world equilibrium price of oil given that $\varepsilon = -0.25$, $\eta = 0.25$, the pre-ANWR daily world production of oil is $Q_1 = 100$ million barrels per day, the pre-ANWR world price is $p_1 = \$70$ per barrel, and daily ANWR production is 0.8 million barrels per day?[20] We assume that the supply and demand curves are linear and that the introduction of ANWR oil would cause a parallel shift in the world supply curve to the right by 0.8 million barrels per day.

Answer

1. *Determine the long-run linear demand function that is consistent with pre-ANWR world output and price.* The general formula for a linear demand curve is $Q = a - bp$, where a is the quantity when $p = 0$ (where the demand curve hits the horizontal axis) and $b = \mathrm{d}Q/\mathrm{d}p$. At the original equilibrium, e_1 in the figure, $p_1 = \$70$ and $Q_1 = 100$ million barrels per day, so the elasticity of demand is $\varepsilon = (\mathrm{d}Q/\mathrm{d}p)(p_1/Q_1) = -b(70/100) = -0.25$. Using algebra, we find that $b = 0.25(100/70) \approx 0.357$, so the demand function is $Q = a - 0.357p$. At e_1, the quantity demanded is $Q = 100 = a - (0.357 \times 70)$. Using algebra, we find that $a = 100 + (0.357 \times 70) = 125$. Thus, the demand function is $Q = 125 - 0.357p$.
2. *Determine the long-run linear supply function that is consistent with pre-ANWR world output and price.* The general formula for a linear supply curve is $Q = c + dp$, where c is the quantity at $p = 0$, and $d = \mathrm{d}Q/\mathrm{d}p$. Where S^1 intercepts D at the original equilibrium, e_1, the elasticity of supply is $\eta = (\mathrm{d}Q/\mathrm{d}p)(p_1/Q_1) = d(70/100) = 0.25$. Solving this equation, we find that $d = 0.25(100/70) \approx 0.357$, so the supply function is $Q = c + 0.357p$. Evaluating this Equation at e_1, $Q = 100 = c + (0.357 \times 70)$. Solving for c, we find that $c = 100 - (0.357 \times 70) = 75$. Thus, the supply function is $Q = 75 + 0.357p$.
3. *Determine the post-ANWR linear supply function.* The oil pumped from the refuge would cause a parallel shift in the supply curve, moving S^1 to the right by 0.8 to S^2. That is, the slope remains the same, but the intercept on the quantity axis increases by 0.8. Thus, the supply function for S^2 is $Q = 75.8 + 0.357p$.
4. *Use the demand curve and the post-ANWR supply function to calculate the new equilibrium price and quantity.* The new equilibrium, e_2, occurs where S^2 intersects D. Setting the right side of the demand function equal to the right side of the post-ANWR supply function, we obtain an expression for the post-Arctic National Wildlife Refuge price, p_2:

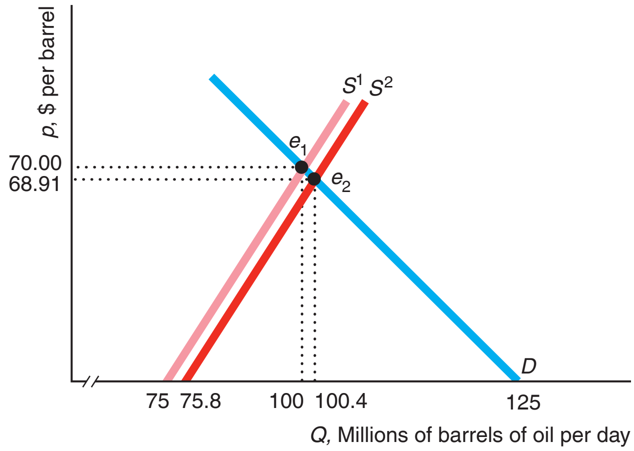
$$125 - 0.357p_2 = 75.8 + 0.357p_2.$$

We can solve this expression for the new equilibrium price: $p_2 \approx \$68.91$. That is, the price drops about \$1.09, or 1.6%. If we substitute this new price into either the demand curve or the post-ANWR supply curve, we find that the new equilibrium quantity is 100.4 million barrels per day. That is, equilibrium output rises by 0.4 million barrels per day (0.4%), which is only a little more than half of the predicted daily refuge supply, because other suppliers will decrease their output slightly in response to the lower price.

[20]This price is for June 2018. From 2007 through 2018, the price of a barrel of oil fluctuated between about \$30 and \$140. The calculated percentage change in the price in Solved Problem 2.5 is not sensitive to the choice of the initial price of oil.

Comment: Our estimate that selling ANWR oil would cause only a small drop in the world oil price would not change substantially if our estimates of the elasticities of supply and demand were moderately larger or smaller or if the equilibrium price of oil were higher or lower. The main reason for this result is that the refuge output would be a very small portion of worldwide supply—the new supply curve would lie only slightly to the right of the initial supply curve. Thus, drilling in ANWR alone cannot insulate the U.S. market from international events that roil the oil market.

In contrast, a new war in the Persian Gulf could shift the worldwide supply curve to the left by up to 24 million barrels per day (the amount of oil produced in the Persian Gulf), or 30 times the ANWR's potential production. Such a shock would cause the price of oil to soar whether we drill in the ANWR or not.



2.6 Effects of a Sales Tax

New Jersey's decision to eliminate the tax on Botox has users elated. At least I think they're elated—I can't really tell.

Before voting for a new sales tax, legislators want to predict the effect of the tax on prices, quantities, and tax revenues. If the new tax will produce a large price increase, legislators who vote for the tax may lose their jobs in the next election. Voters' ire is likely to be even greater if the tax fails to raise significant tax revenues.

Governments use two types of sales taxes: ad valorem and specific taxes. Economists call the most common sales tax an *ad valorem* tax, while real people call it *the* sales tax. For every dollar the consumer spends, the government keeps a fraction, v, which is the ad valorem tax rate. For example, Japan's national ad valorem sales tax is 8%. If a Japanese consumer buys a Nintendo Wii for ¥40,000,[21] the government

[21]The symbol for Japan's currency, the yen, is ¥. Roughly, ¥111 = $1.

collects $v \times$ ¥40,000 = 8% $\times$ ¥40,000 = ¥3,200 in taxes, and the seller receives $(1 - v) \times$ ¥40,000 = 92% $\times$ ¥40,000 = ¥36,800.[22]

The other type of sales tax is a *specific* or *unit* tax: The government collects a specified dollar amount, t, per unit of output. For example, the federal government collects $t = 18.4¢$ on each gallon of gas sold in the United States.

In this section, we examine four questions about the effects of sales taxes:

1. What effect does a specific sales tax have on the equilibrium price, the equilibrium quantity, and tax revenue?
2. Are the equilibrium price and quantity dependent on whether the government collects the specific tax from suppliers or their customers?
3. Is it true, as many people claim, that producers *pass along* to consumers any taxes collected from producers? That is, do consumers pay the entire tax?
4. Do comparable ad valorem and specific taxes have equivalent effects on equilibrium prices and quantities and on tax revenue?

The shapes of the supply and demand curves determine how much a tax affects the equilibrium price and quantity and how much of the tax consumers pay. Knowing only the elasticities of supply and demand, which summarize the shapes of these curves, we can make accurate predictions about the effects of a new tax and determine how much of the tax is paid by consumers.

Effects of a Specific Tax on the Equilibrium

We use our estimated corn supply and demand curves to illustrate the answer to our first question: What effect does a specific sales tax have on the equilibrium price, the equilibrium quantity, and tax revenue?[23]

Panel a of Figure 2.12 shows that in the before-tax equilibrium, e_1, where S^1 and D^1 intersect, the equilibrium price is $p_1 = \$7.20$ and the equilibrium quantity is $Q_1 = 12$ billion bushels of corn.

Suppose the government imposes a specific tax of $t = \$2.40$ per bushel of corn on firms. If a customer pays a price of p to a firm, the government takes t, so the firm keeps $p - t$. Thus, at every possible price paid by customers, firms are willing to supply less than when they received the full amount that customers paid. Before the tax, firms were willing to supply 11.6 billion bushels of corn per year at a price of \$5.60 per bushel, as the pre-tax supply curve S^1 in panel a shows. After the tax, if customers pay \$5.60, firms receive only \$3.20 (= \$5.60 − \$2.40), so they are not willing to supply 11.6 billion bushels. For firms to be willing to supply that quantity, customers must pay \$8.00 so that firms receive \$5.60 (= \$8.00 − \$2.40) after paying the tax. By this reasoning, the after-tax supply curve, S^2, is $t = \$2.40$ above the original supply curve S^1 at every quantity, as the figure shows.

The after-tax supply curve S^2 intersects the demand curve D^1 at e_2. In the after-tax equilibrium, consumers pay $p_2 = \$8$ and buy $Q_2 = 11.6$ billion bushels. At that quantity, firms receive the price corresponding to e_3 on the original supply curve, $p_2 - t = \$5.60$. Thus, the tax causes the equilibrium price that customers pay to

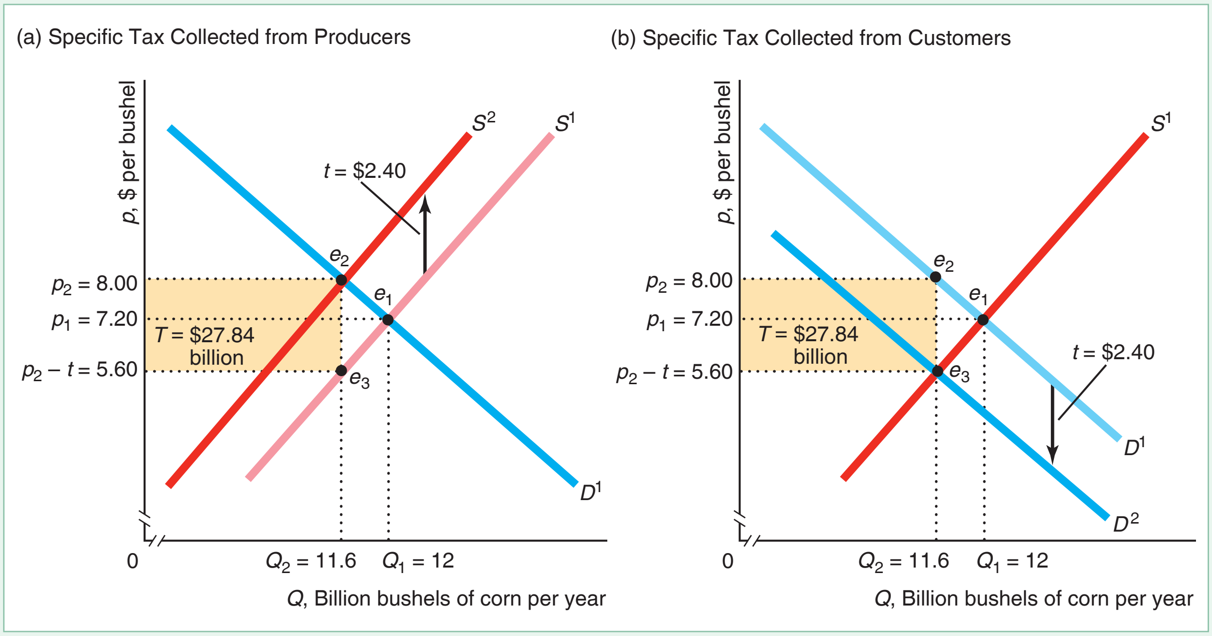
---

[22]For specificity, we assume that the price firms receive is $p = (1 - v)p^*$, where p^* is the price consumers pay and v is the ad valorem tax rate on the price consumers pay. However, many governments set the ad valorem sales tax, V, as an amount added to the price sellers charge, so consumers pay $p^* = (1 + V)p$. By setting v and V appropriately, the taxes are equivalent. Here $p = p^*/(1 + V)$, so $(1 - v) = 1/(1 + V)$. For example, if $V = \frac{1}{3}$, then $v = \frac{1}{4}$.

[23]**MyLab Economics** has a *Taxes Experiment* that illustrates the effect of sales taxes. To participate, go to the **MyLab Economics** Multimedia Library, Single Player Experiment, and set the Chapter field to "All Chapters."

Figure 2.12 The Equilibrium Effects of a Specific Tax

(a) The specific tax of $t = \$2.40$ per bushel of corn collected from producers shifts the pre-tax corn supply curve, S^1, up to the post-tax supply curve, S^2. The tax causes the equilibrium to shift from e_1 (determined by the intersection of S^1 and D^1) to e_2 (intersection of S^2 with D^1). The equilibrium price—the price consumers pay—increases from $p_1 = \$7.20$ to $p_2 = \$8.00$. The government collects tax revenues of $T = tQ_2 = \$27.84$ billion per year. (b) The specific tax collected from customers shifts the demand curve down by $t = \$2.40$ from D^1 to D^2. The intersection of D^2 and S^1 determines the new price that firms receive, $p_2 - t = \$5.60$, at e_3. Corresponding to this point is e_2 on D^1, which shows the equilibrium price that consumers pay, $p_2 = \$8.00$, is the same as when the tax is applied to suppliers in panel a.



increase ($\Delta p = p_2 - p_1 = \$8 - \$7.20 = 80¢$) and the equilibrium quantity to fall ($\Delta Q = Q_2 - Q_1 = 11.6 - 12 = -0.4$).

Although the customers and producers are worse off because of the tax, the government acquires tax revenue of $T = tQ = \$2.40$ per bushel $\times$ 11.6 billion bushels per year = \$27.84 billion per year. The length of the shaded rectangle in Figure 2.12 panel a is $Q_2 = 11.6$ billion per year, and its height is $t = \$2.40$ per bushel, so the area of the rectangle equals the tax revenue.

Thus, the answer to our first question is that a specific tax causes the equilibrium price customers pay to rise, the price that firms receive to fall, the equilibrium quantity to fall, and tax revenue to rise. Usually, a government imposes a tax to obtain tax revenue, which is a desired intended consequence of the tax. However, it views the other effects as predictable, but unfortunate:

Unintended Consequences A sales tax usually causes the price to consumers to rise, the price received by firms to fall, and the quantity sold to drop.

Of course, a government may tax "sin" goods—such as alcohol, marijuana, and soda—to discourage consumption, in which case these price and quantity effects are intended and desired.

The Same Equilibrium No Matter Who Is Taxed

Our second question is, "Are the equilibrium price and quantity dependent on whether the specific tax is collected from suppliers or their customers?" We can use our supply-and-demand model to answer this question, showing that the equilibrium is the same regardless of whether the government collects the tax from suppliers or their customers.

If a customer pays a firm p for a bushel of corn, and the government collects a specific tax t from the customer, the total the customer pays is $p + t$. Suppose that customers bought a quantity Q at a price p^* before the tax. After the tax, they are willing to continue to buy Q only if the price falls to $p^* - t$, so that the after-tax price, $p^* - t + t$, remains at p^*. Consequently, the demand curve, from the perspective of firms, shifts down by $t = \$2.40$ from D^1 to D^2 in panel b of Figure 2.12.

The intersection of D^2 and the supply curve S^1 determines e_3. At e_3, the price received by producers is $p_2 - t = \$5.60$ and the quantity is $Q_2 = 11.6$ billion bushels. At this after-tax quantity on D^1 is e_2, where the price consumers pay is $p_2 = \$8$. The tax revenue that the government collects is $T = \$27.84$ billion.

Comparing the two panels in Figure 2.12, we see that the after-tax equilibrium prices, quantities, and tax revenue are the same regardless of whether the government imposes the tax on consumers or sellers. Consequently, regardless of whether sellers or buyers pay the tax to the government, you can solve tax problems by shifting the supply curve or by shifting the demand curve.

Firms and Customers Share the Burden of the Tax

Our third question concerns whether customers bear the entire burden of a tax, as many politicians and news stories assert.

Common Confusion Businesses pass any sales tax along to consumers, so that the entire burden of the tax falls on consumers.

This claim is not generally true, as we now demonstrate. We start by determining the share of the tax that consumers bear and then show how that share depends on the elasticities of supply and demand.

Tax Incidence. The **incidence of a tax on consumers** is the share of the tax that consumers pay. We start by illustrating this concept in our corn example for a discrete change in the tax. If the government sets a new specific tax of t, the change in the tax from 0 to t is $\Delta t = t - 0 = t$. The incidence of the tax on consumers is the amount by which the price consumers pay rises as a fraction of the amount the tax increases: $\Delta p/\Delta t$.

In the corn example, as both panels of Figure 2.12 show, a $\Delta t = \$2.40$ increase in the specific tax causes customers to pay $\Delta p = 80¢$ more per bushel than before the tax. Thus, customers bear one-third of the incidence of the corn tax: $\Delta p/\Delta t = \$0.80/\$2.40 = \frac{1}{3}$.

The change in the price that firms receive is $(p_2 - t) - p_1 = (\$8 - \$2.40) - \$7.20 = \$5.60 - \$7.20 = -\$1.60$. That is, they receive \$1.60 less per bushel than they would in the absence of the tax. Thus, the incidence of the tax on firms—the amount by which the price firms receives falls, divided by the tax—is $\$1.60/\$2.40 = \frac{2}{3}$.

The sum of the share of the tax on customers, $\frac{1}{3}$, and that on firms, $\frac{2}{3}$, equals the entire tax effect, 1. Equivalently, the price increase to customers minus the price decrease to farmers equals the tax: $\$0.80 - (-\$1.60) = \$2.40 = t$.

The Incidence Depends on Elasticities. The tax incidence on customers depends on the elasticities of supply and demand, as we illustrate for small changes in the unit tax, t. If the government collects t from sellers, sellers receive $p - t$ when consumers pay p. We can use this information to determine the effect of the tax on the equilibrium. In the new equilibrium, the price that consumers pay is determined by the equality between the demand function and the after-tax supply function, $D(p) = S(p - t)$. As a result, the equilibrium price varies with t, so we can write the equilibrium price as an implicit function of the tax: $p = p(t)$. Consequently, the equilibrium condition is

$$D(p(t)) = S(p(t) - t). \tag{2.28}$$

We determine the effect a small change in the tax has on the price by differentiating Equation 2.28 with respect to t:

$$\frac{\mathrm{d}D}{\mathrm{d}p}\frac{\mathrm{d}p}{\mathrm{d}t} = \frac{\mathrm{d}S}{\mathrm{d}p}\frac{\mathrm{d}(p(t) - t)}{\mathrm{d}t} = \frac{\mathrm{d}S}{\mathrm{d}p}\left(\frac{\mathrm{d}p}{\mathrm{d}t} - 1\right).$$

By rearranging these terms, we discover that the change in the price that consumers pay with respect to the change in the tax is

$$\frac{\mathrm{d}p}{\mathrm{d}t} = \frac{\dfrac{\mathrm{d}S}{\mathrm{d}p}}{\dfrac{\mathrm{d}S}{\mathrm{d}p} - \dfrac{\mathrm{d}D}{\mathrm{d}p}}. \tag{2.29}$$

We know that $\mathrm{d}D/\mathrm{d}p < 0$ from the Law of Demand. If the supply curve slopes upward (as in Figure 2.12), $\mathrm{d}S/\mathrm{d}p > 0$, so $\mathrm{d}p/\mathrm{d}t > 0$. The higher the tax, the greater the price consumers pay. If $\mathrm{d}S/\mathrm{d}p < 0$, the direction of change is ambiguous: It depends on the relative slopes of the supply and demand curves (the denominator).

By multiplying both the numerator and denominator of the right side of Equation 2.29 by p/Q, we can express this derivative in terms of elasticities,

$$\frac{\mathrm{d}p}{\mathrm{d}t} = \frac{\dfrac{\mathrm{d}S}{\mathrm{d}p}\dfrac{p}{Q}}{\dfrac{\mathrm{d}S}{\mathrm{d}p}\dfrac{p}{Q} - \dfrac{\mathrm{d}D}{\mathrm{d}p}\dfrac{p}{Q}} = \frac{\eta}{\eta - \varepsilon}, \tag{2.30}$$

where the last equality follows because $\mathrm{d}S/\mathrm{d}p$ and $\mathrm{d}D/\mathrm{d}p$ are the changes in the quantities supplied and demanded as price changes, and the consumer and producer prices are identical when $t = 0$.[24] This expression holds for any size change in t if both the demand and supply curves are linear. For most other shaped curves, the expression holds only for small changes.

At the corn equilibrium, $\varepsilon = -0.3$ and $\eta = 0.15$, so the incidence of a specific tax on consumers is $\mathrm{d}p/\mathrm{d}t = \eta/(\eta - \varepsilon) = 0.15/[0.15 - (-0.3)] = 0.15/0.45 = \frac{1}{3}$, and the incidence of the tax on firms is $1 - \frac{1}{3} = \frac{2}{3}$.

Equation 2.30 shows that, for a given supply elasticity, the more elastic the demand curve at the equilibrium, the less the equilibrium price rises when a tax is imposed.

[24]To determine the effect on quantity, we can combine the price result from Equation 2.29 with information from either the demand or the supply function. For example, differentiating the demand function with respect to t, we know that $\frac{\mathrm{d}D}{\mathrm{d}p}\frac{\mathrm{d}p}{\mathrm{d}t} = \frac{\mathrm{d}D}{\mathrm{d}p}\frac{\eta}{\eta - \varepsilon}$, which is negative if the supply curve is upward sloping, so $\eta > 0$.

Similarly, for a given demand elasticity, the smaller the supply elasticity, the smaller the increase in the equilibrium price that consumers pay in response to a tax. In the corn example, if the supply elasticity changed to $\eta = 0$ (a perfectly inelastic vertical supply curve) and ε remained -0.3, then $dp/dt = 0/[0 - (-0.3)] = 0$. Here, none of the incidence of the tax falls on consumers, so the entire incidence of the tax falls on firms.

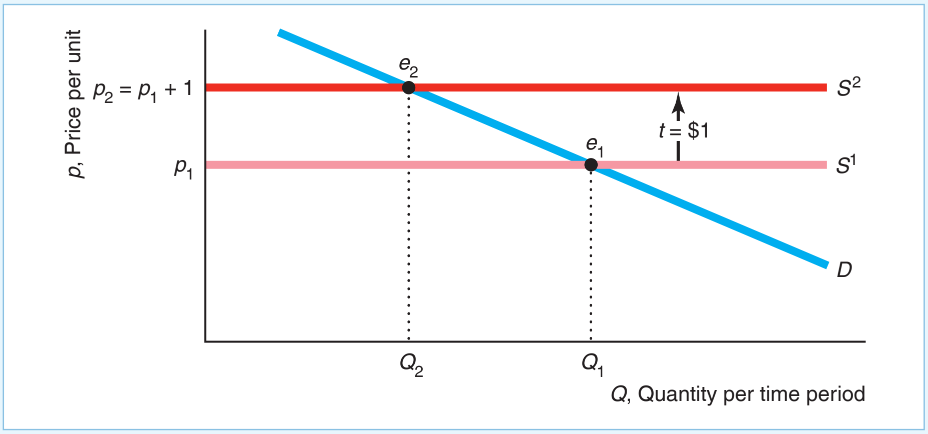
SOLVED PROBLEM 2.6

MyLab Economics Solved Problem

If the supply curve is perfectly elastic and the demand curve is linear and downward sloping, what is the effect of a \$1 specific tax collected from producers on equilibrium price and quantity, and what is the incidence on consumers? Why?

Answer

1. *Determine the equilibrium in the absence of a tax.* Before the tax, the perfectly elastic supply curve, S^1 in the graph, is horizontal at p_1. The downward-sloping linear demand curve, D, intersects S^1 at the pre-tax equilibrium, e_1, where the price is p_1 and the quantity is Q_1.



2. *Show how the tax shifts the supply curve and determine the new equilibrium.* A specific tax of \$1 shifts the pre-tax supply curve, S^1, upward by \$1 to S^2, which is horizontal at $p_1 + 1$. The intersection of D and S^2 determines the after-tax equilibrium, e_2, where the price consumers pay is $p_2 = p_1 + 1$, the price firms receive is $p_2 - 1 = p_1$, and the quantity is Q_2.
3. *Compare the before- and after-tax equilibria.* The specific tax causes the equilibrium quantity to fall from Q_1 to Q_2, the price firms receive to remain at p_1, and the equilibrium price consumers pay to rise from p_1 to $p_2 = p_1 + 1$. The entire incidence of the tax falls on consumers:

$$\frac{\Delta p}{\Delta t} = \frac{p_2 - p_1}{\Delta t} = \frac{\$1}{\$1} = 1.$$

(We can use Equation 2.30 to draw the same conclusion.)

4. *Explain why.* The reason consumers must absorb the entire tax is that firms will not supply the good at a price that is any lower than they received before the tax, p_1. Thus, the price must rise enough that the price suppliers receive after tax is unchanged. As consumers do not want to consume as much at a higher price, the equilibrium quantity falls.

APPLICATION

Subsidizing Ethanol

For 30 years, the U.S. government subsidized ethanol directly and indirectly with the goal of replacing 15% of U.S. gasoline consumption with this biofuel. The explicit ethanol subsidy was eliminated in 2012.[25] However, as of 2018, the government continues to subsidize corn, the main input, and requires that gas stations sell a gasoline-ethanol mix, which greatly increases the demand for ethanol.

What was the subsidy's incidence on consumers? That is, how much of the subsidy went to purchasers of ethanol? Because a subsidy is a negative tax, we need to change the sign of the consumer incidence formula, Equation 2.30, when using it for a subsidy, s, rather than for a tax. That is, the consumer incidence is $\mathrm{d}p/\mathrm{d}s = \eta/(\varepsilon - \eta)$.

According to McPhail and Babcock (2012), the supply elasticity of ethanol, η, is about 0.13, and the demand elasticity is about -2.1. Thus, at the equilibrium, the supply curve is relatively inelastic (nearly the opposite of the situation in Solved Problem 2.6, where the supply curve was perfectly elastic), and the demand curve is relatively elastic. Using Equation 2.30, the consumer incidence was $\eta/(\eta - \varepsilon) = 0.13/(-2.1 - 0.13) \approx -0.06$. Thus, consumers received virtually none (6%) of the subsidy, so producers captured almost the entire subsidy. A detailed empirical study by Bielen, Newell, and Pizer (2018) confirmed these results: Consumers and corn farmers received a negligible amount of the benefits from the ethanol subsidy, with virtually all of the benefits going to ethanol producers and gasoline blenders.

The Similar Effects of Ad Valorem and Specific Taxes

Our fourth question concerns whether comparable ad valorem and specific taxes have the same equilibrium and revenue effects. Unlike specific sales taxes, which are applied to relatively few goods, governments levy ad valorem taxes on a wide variety of goods. Most states apply ad valorem sales taxes to most goods and services, exempting only a few staples such as food and medicine.

Suppose the government imposes an ad valorem tax of v, instead of a specific tax, on the price that consumers pay for corn. We already know that the equilibrium price of corn is \$8.00 with a specific tax of \$2.40 per bushel. At that price, an ad valorem tax of $v = \$2.40/\$8 = 30\%$ raises the same amount of tax per unit as a \$2.40 specific tax.

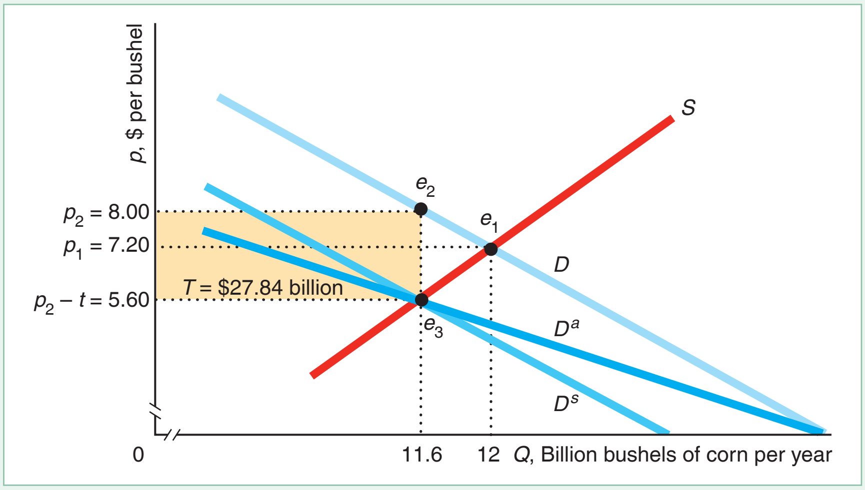
It is usually easiest to analyze the effects of an ad valorem tax by shifting the demand curve. Figure 2.13 shows how a specific tax and an ad valorem tax shift the corn demand curve. The specific tax shifts the original, pre-tax demand curve, D, down to D^s, which is parallel to the original curve. The ad valorem tax rotates the demand curve to D^a. At any given price p, the gap between D and D^a is vp, which is greater at high prices than at low prices. The gap is \$2.40 (= $0.3 \times \$8$) per unit when the price is \$8, and \$1.20 when the price is \$4.

If the government imposes the ad valorem tax, D^a intersects S at e_3. The equilibrium quantity falls from 12 billion bushels to 11.6 billion bushels at e_1. The after-tax price, $p_2 = \$8$, at e_2 is higher than the original price, $p_1 = \$7.20$, at e_1. The tax collected per unit of output is $t = vp_2 = \$2.40$. The incidence of the tax that falls on consumers is the change in price, $\Delta p = p_2 - p_1 = \$0.80$, divided by the change in the per-unit tax, $\Delta t = vp_2 - 0 = \$2.40$, that is collected, $\Delta p/(vp_2) = \$0.80/\$2.40 = \frac{1}{3}$.

[25] In 2011, the last year of the ethanol subsidy, the subsidy cost the government \$6 billion. According to a 2010 Rice University study, in 2008, ethanol replaced about 2% of the U.S. gasoline supply, at a cost of about \$1.95 per gallon on top of the gasoline retail price. The combined ethanol and corn subsidies amounted to about \$2.59 per gallon of ethanol.

Figure 2.13 The Effects of a Specific Tax and an Ad Valorem Tax on Consumers

Without a tax, the demand curve is D and the supply curve is S. An ad valorem tax of $v = 30\%$ shifts the demand curve facing firms to D^a. The gap between D and D^a, the per-unit tax, is larger at higher prices. In contrast, the demand curve facing firms given a specific tax of \$2.40 per bushel, D^s, is parallel to D. The after-tax equilibrium, e_2, and the tax revenue, T, are the same with both of these taxes.



The incidence of an ad valorem tax is generally shared between consumers and producers. Because the ad valorem tax of $v = 30\%$ has exactly the same impact on the equilibrium corn price and raises the same amount of tax per unit as the $t = \$2.40$ specific tax, the incidence is the same for both types of taxes. (As with specific taxes, the incidence of the ad valorem tax depends on the elasticities of supply and demand, but we'll spare you from having to go through that in detail.)

2.7 Quantity Supplied Need Not Equal Quantity Demanded

In a supply-and-demand model, the quantity supplied does not necessarily equal the quantity demanded because of the way we defined these two concepts. We defined the quantity supplied as the amount firms want to sell at a given price, holding constant other factors that affect supply, such as the price of inputs. We defined the quantity demanded as the quantity that consumers want to buy at a given price, if other factors that affect demand are held constant. The quantity that firms want to sell and the quantity that consumers want to buy at a given price need not equal the quantity that is bought and sold.

We could have defined the quantity supplied and the quantity demanded so that they must be equal. Had we defined the quantity supplied as the amount firms *actually* sell at a given price and the quantity demanded as the amount consumers *actually* buy, supply would have to equal demand in all markets because we *defined* the quantity demanded and the quantity supplied as the same quantity.

It is worth emphasizing this distinction because politicians, pundits, and the press are so often confused on this point. Someone who insists "demand *must* equal supply" must be defining demand and supply as the *actual* quantities sold. Because we define the quantities supplied and demanded in terms of people's *wants* and not *actual* quantities bought and sold, the statement that "supply equals demand" is a theory, not merely a definition.

According to our theory, the quantity supplied equals the quantity demanded at the intersection of the supply and demand curves if the government does not intervene. However, not all government interventions prevent markets from *clearing*: equilibrating the quantity supplied and the quantity demanded. For example, as we've seen, a government tax affects the equilibrium by shifting the supply curve or demand curve of a good but does not cause a gap between the quantity demanded and the quantity supplied. However, some government policies do more than merely shift the supply curve or demand curve.

For example, governments may directly control the prices of some products. New York City, for instance, limits the price or rent that property owners can charge for an apartment. If the price a government sets for a product differs from its market clearing price, either excess supply or excess demand results. We illustrate this result with two types of price control programs. The government may set a *price ceiling* at $\bar{p}$ so that the price at which goods are sold may be no higher than $\bar{p}$. When the government sets a *price floor* at $\underline{p}$, the price at which goods are sold may not fall below $\underline{p}$.[26]

We can study the effects of such regulations using the supply-and-demand model. Despite the lack of equality between the quantity supplied and the quantity demanded, the supply-and-demand model is useful for analyzing price controls because it predicts the excess demand or excess supply that is observed.

Price Ceiling

A price ceiling legally limits the amount that a firm can charge for a product. The ceiling does not affect market outcomes if it is set above the equilibrium price that would be charged in the absence of the price control. For example, if the government says firms can charge no more than $\bar{p} = \$5$ per gallon of gas and firms are actually charging $p = \$3$, the government's price control policy is irrelevant. However, if the equilibrium price had been $6 per gallon, the price ceiling would limit the price in that market to only $5.

Currently, Canada and many European countries set price ceilings on pharmaceuticals. The United States used price ceilings during both world wars, the Korean War, and in 1971–1973 during the Nixon administration, among other times. Many states impose price controls during a declared state of emergency.

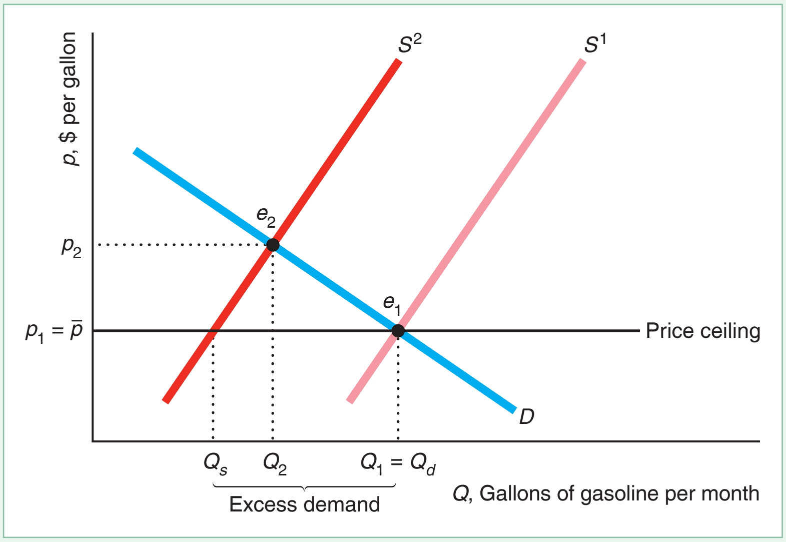
The U.S. government imposed price controls on gasoline several times. In the 1970s, the Organization of Petroleum Exporting Countries (OPEC) reduced supplies of oil—which is converted into gasoline—to Western countries. As a result, the total supply curve for gasoline in the United States—the horizontal sum of domestic and OPEC supply curves—shifted to the left from S^1 to S^2 in Figure 2.14. Because of this shift, the equilibrium price of gasoline would have risen substantially, from p_1 to p_2. In an attempt to protect consumers by keeping gasoline prices from rising, the U.S. government set price ceilings on gasoline in 1973 and 1979.

The government told gas stations that they could charge no more than $p_1 = \bar{p}$. Figure 2.14 shows the price ceiling as a solid horizontal line extending from the price axis at $\bar{p}$. The price control is binding because $p_2 > \bar{p}$. The observed price is the price ceiling. At $\bar{p}$, consumers *want* to buy $Q_d = Q_1$ gallons of gasoline, which is the equilibrium quantity they bought before OPEC acted. However, because of the

[26]MyLab Economics has a *Price Ceilings Experiment* and a *Price Floors Experiment* that illustrate the operation of price controls. To participate, go to the MyLab Economics Multimedia Library, Single Player Experiment, and set the Chapter field to "All Chapters."

Figure 2.14 The Effects of a Gasoline Price Ceiling

Supply shifts from S^1 to S^2. Under the government's price control program, gasoline stations may not charge a price above the price ceiling $\bar{p} = p_1$. At that price, producers are willing to supply only Q_s, which is less than the amount $Q_1 = Q_d$ that consumers want to buy. The result is excessive demand, or a shortage of $Q_d - Q_s$.



price control, firms are willing to supply only Q_s, which is determined by the intersection of the price control line with S^2. As a result, a binding price control causes excess demand of $Q_d - Q_s$.

Were it not for the price controls, market forces would drive up the market price to p_2, where the excess demand would be eliminated. The government's price ceiling prevents this adjustment from occurring, which causes a **shortage**, or persistent excess demand.

Unintended Consequence A price control causes shortages.

At the time the controls were implemented, some government officials falsely contended that the shortages were the result of OPEC's cutting off its supply of oil to the United States, but that's not true. Without the price controls, the new equilibrium would be e_2, where the equilibrium price, p_2, is greater than p_1, and the equilibrium, Q_2, is greater than the quantity sold under the control program, Q_s. Allowing the price to rise to p_2 would have prevented a shortage.

The supply-and-demand model predicts that a binding price control results in equilibrium *with a shortage*. In this equilibrium, the quantity demanded does not equal the quantity supplied. The reason that we call this situation an equilibrium even though a shortage exists is that no consumers or firms want to act differently, *given the law*. Without a price control, consumers facing a shortage would try to get more output by offering to pay more, or firms would raise their prices. With an enforced price control, consumers know that they can't drive up the price, so they live with the shortage.

So what happens when a shortage occurs? Lucky consumers get to buy Q_s units at the low price of $\bar{p}$. Other potential customers are disappointed: They would like to buy at that price, but they cannot find anyone willing to sell gas to them. With enforced price controls, sellers use criteria other than price to allocate the scarce commodity. They may supply the commodity to their friends; long-term customers;

or people of a certain race, gender, age, or religion. They may sell their goods on a first-come, first-served basis. Or they may limit everyone to only a few gallons.

Another possibility is for firms and customers to evade the price controls. A consumer could go to a gas station owner and say, “Let’s not tell anyone, but I’ll pay you twice the price the government sets if you’ll sell me as much gas as I want.” If enough customers and gas station owners behaved that way, no shortage would occur. A study of 92 major U.S. cities during the 1973 gasoline price control found no gasoline lines in 52 of the cities, where apparently the law was not enforced. However, in cities where the law was effective, such as Chicago, Hartford, New York, Portland, and Tucson, potential customers waited in line at the pump for an hour or more. Deacon and Sonstelie (1989) calculated that for every dollar consumers saved during the 1980 gasoline price controls, they lost $1.16 in waiting time and other factors.

APPLICATION

Venezuelan Price Ceilings and Shortages

Venezuela is one of the richest countries in Latin America. It is a leading oil producer, and it has many other agricultural and nonagricultural industries.

So, why do people start lining up to buy groceries in Venezuela at 4 a.m., when shops open at 8 a.m.? Strict price ceilings on food and other goods create shortages throughout the country.

According to a university study in 2018, one-quarter of Venezuelans eat two or fewer meals a day, 60% reported waking up hungry, and people reported losing 24 lb of weight, on average, during the previous year. Venezuelans also suffer from condom, birth control pill, and toilet paper shortages.

One would think that Venezuela should be able to supply its citizens with coffee, which it has been producing in abundance for centuries. Indeed, Venezuela exported coffee until 2009. However, since then, it has been importing large amounts of coffee to compensate for a drop in production. Why have farmers and coffee roasters cut production? Due to low retail price ceilings, they would have to produce at a loss.

Because Venezuela regulates the prices of many goods such as gasoline and corn flour, while Colombia, its direct neighbor to the west, does not, smuggling occurs. Given that gasoline sold in 2015 for 4¢ a gallon in Venezuela, and the price was 72¢ a gallon in most of Colombia, the temptation to smuggle is great. Venezuela’s Táchira state is adjacent to the Colombian border. Its government says that as much as 40% of the food sent to Táchira is smuggled into Colombia. Why sell corn flour at an artificially low price in Venezuela if you can sell it at a higher, market price in Colombia?

Venezuela’s populist President Hugo Chávez and his hand-picked successor, Nicolás Maduro, imposed strict price ceilings purportedly to rein in inflation and make the goods more affordable for the poor. Do the ceilings help the poor?

For many Venezuelans, the answer is “No!” As Nery Reyes, a restaurant worker, said, “Venezuela is too rich a country to have this. I’m wasting my day here standing in line to buy one chicken and some rice.”

Demonstrators have taken to the streets to protest persistent economic and social problems, including shortages. Many have died in these violent clashes with the National Guard. Hundreds of thousands of people have left Venezuela, and more than half of those between the ages of 15 and 29 say they want to leave the country.

The ultimate irony was that President Nicolás Maduro advised Venezuelans to consume less to alleviate the shortages.

Price Floor

Governments also commonly impose price floors. One of the most important examples of a price floor is the minimum wage in labor markets.

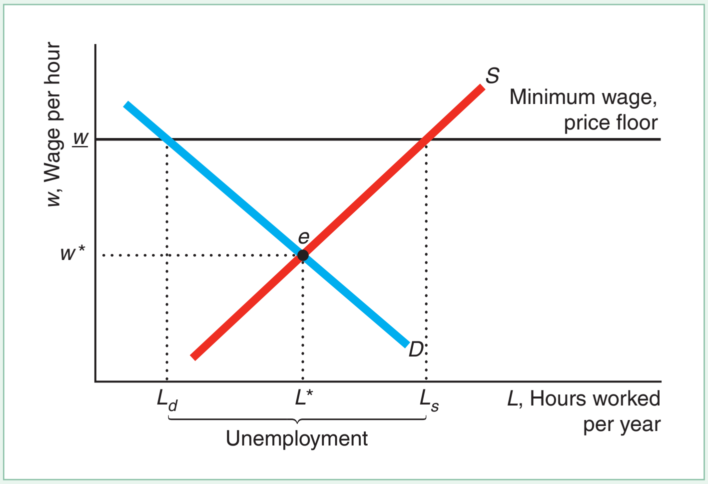
Minimum wage laws date from 1894 in New Zealand, 1909 in the United Kingdom, and 1912 in Massachusetts. The Fair Labor Standards Act of 1938 set a federal U.S. minimum wage of 25¢ per hour. The U.S. federal minimum hourly wage rose to $7.25 in 2009 and remained at that level through early 2018, but 29 states and a number of cities set higher minimum wages.[27] As of 2018, the highest minimum wage is in Washington D.C. ($12.50), followed by Washington State ($11.50), California ($11.00), and Massachusetts ($11.00).

The minimum wage in Canada differs across provinces, ranging from C$14.00 to C$10.96 (where C$ stands for Canadian dollars) in 2018. In 2018, the United Kingdom's minimum hourly wage is £7.83 for adult workers.

If the minimum wage binds—exceeds the equilibrium wage, w^*—the minimum wage causes *unemployment*, which is a persistent excess supply of labor. For simplicity, we examine a labor market in which everyone receives the same wage.[28] Figure 2.15 shows the supply and demand curves for labor services (hours worked). Firms buy hours of labor service—they hire workers. The quantity measure on the horizontal axis is hours worked per year, and the price measure on the vertical axis is the wage per hour.

Figure 2.15 The Effects of a Minimum Wage

In the absence of a minimum wage, the equilibrium wage is w^*, and the equilibrium number of hours worked is L^*. A minimum wage, $\underline{w}$, set above w^*, leads to unemployment—persistent excess supply—because the quantity demanded, L_d, is less than the quantity supplied, L_s.



[27]See **www.dol.gov** for U.S. state and federal minimum wages. See **www.fedee.com/pay-job-evaluation/minimum-wage-rates/** for minimum wages in European countries.

[28]Where the minimum wage applies to only some labor markets (Chapter 10) or where only a single firm hires all the workers in a market (Chapter 11), a minimum wage might not cause unemployment. Card and Krueger (1995) argued, based on alternatives to the simple supply-and-demand model, that minimum wage laws raise wages in some markets (such as fast foods) without significantly reducing employment. In contrast, Neumark, Salas, and Wascher (2014) concluded, based on an extensive review of minimum wage research, that increases in the minimum wage often have negative effects on employment.

With no government intervention, the market equilibrium is e, where the wage is w^* and the number of hours worked is L^*. The minimum wage creates a price floor, a horizontal line, at $\underline{w}$. At that wage, the quantity demanded falls to L_d and the quantity supplied rises to L_s. The result is an excess supply or unemployment of $L_s - L_d$. The minimum wage prevents market forces from eliminating the excess supply, so it leads to an equilibrium with unemployment. The original 1938 U.S. minimum wage law caused massive unemployment in the U.S. territory of Puerto Rico.

It is ironic that a law designed to help workers by raising their wages may harm some workers.

Unintended Consequence If a minimum wage applies to all workers in a competitive market, it may cause some workers to become unemployed.

Thus, minimum wage laws benefit only people who manage to remain employed.

2.8 When to Use the Supply-and-Demand Model

As we've seen, the supply-and-demand model can help us understand and predict real-world events in many markets. Through Chapter 10, we discuss *perfectly competitive* markets, in which the supply-and-demand model is a powerful tool for predicting what will happen to market equilibrium if underlying conditions—tastes, incomes, and prices of inputs—change. A perfectly competitive market (Chapter 8) is one in which all firms and consumers are *price takers*: No market participant can affect the market price.

Perfectly competitive markets have five characteristics that result in price-taking behavior:

1. The market has many small buyers and sellers.
2. All firms produce identical products.
3. All market participants have full information about prices and product characteristics.
4. Transaction costs are negligible.
5. Firms can easily enter and exit the market.

In a market with many firms and consumers, no single firm or consumer is a large enough part of the market to affect the price. If you stop buying bread or if one of the many thousands of wheat farmers stops selling the wheat used to make the bread, the price of bread will not change.

In contrast, if a market has only one seller of a good or service—a *monopoly* (Chapter 11)—that seller is a *price setter* and can affect the market price. Because demand curves slope downward, a monopoly can increase the price it receives by reducing the amount of a good it supplies. Firms are also price setters in an *oligopoly*—a market with only a small number of firms—or in markets in which they sell differentiated products and consumers prefer one product to another (Chapter 14), such as the automobile market. In markets with price setters, the market price is usually higher than that predicted by the supply-and-demand model. That doesn't make the supply-and-demand model generally wrong. It means only that the supply-and-demand model does not apply to those markets.

If consumers believe all firms produce identical products, consumers do not prefer one firm's good to another's. Thus, if one firm raises its price, consumers buy from the other firm. In contrast, if some consumers prefer Coke to Pepsi, Coke can charge more than Pepsi and not lose all its customers.

If consumers know the prices all firms charge and one firm raises its price, that firm's customers will buy from other firms. If consumers have less information about a product's quality than the firm that produces it, the firm can take advantage of consumers by selling them inferior-quality goods or by charging a higher price than other firms charge. In such a market, the observed price may be higher than that predicted by the supply-and-demand model, the market may not exist at all (consumers and firms cannot reach agreements), or different firms may charge different prices for the same good (Chapter 18).

If it is cheap and easy for a buyer to find a seller and make a trade, and if one firm raises its price, consumers can easily arrange to buy from another firm. That is, perfectly competitive markets typically have very low **transaction costs**: the expenses, over and above the price of the product, of finding a trading partner and making a trade for the product. These costs include the time and money spent gathering information about a product's quality and finding someone with whom to trade. Other transaction costs include the costs of writing and enforcing a contract, such as the cost of a lawyer's time. If transaction costs are very high, no trades at all might occur. In less extreme cases, individual trades may occur, but at a variety of prices.

The ability of firms to enter and exit a market freely leads to a large number of firms in a market and promotes price taking. Suppose a firm could raise its price and make a higher profit. If other firms could not enter the market, this firm would not be a price taker. However, if other firms can quickly and easily enter the market, the higher profit will encourage entry until the price is driven back to its original level.

Thus, the supply-and-demand model is not appropriate in markets that have

- only one or a few sellers, such as the market for local water and sewage services,
- firms producing differentiated products, such as music CDs,
- consumers who know less than sellers about the quality of products or their prices, such as used cars,
- consumers incurring high transaction costs, such as nuclear turbine engines, or
- firms facing high entry or exit costs, such as aircraft manufacturing.

Markets in which the supply-and-demand model has proved useful—markets with many firms and consumers and in which firms sell identical products—include agriculture, finance, labor, construction, services, wholesale, and retail.

CHALLENGE SOLUTION

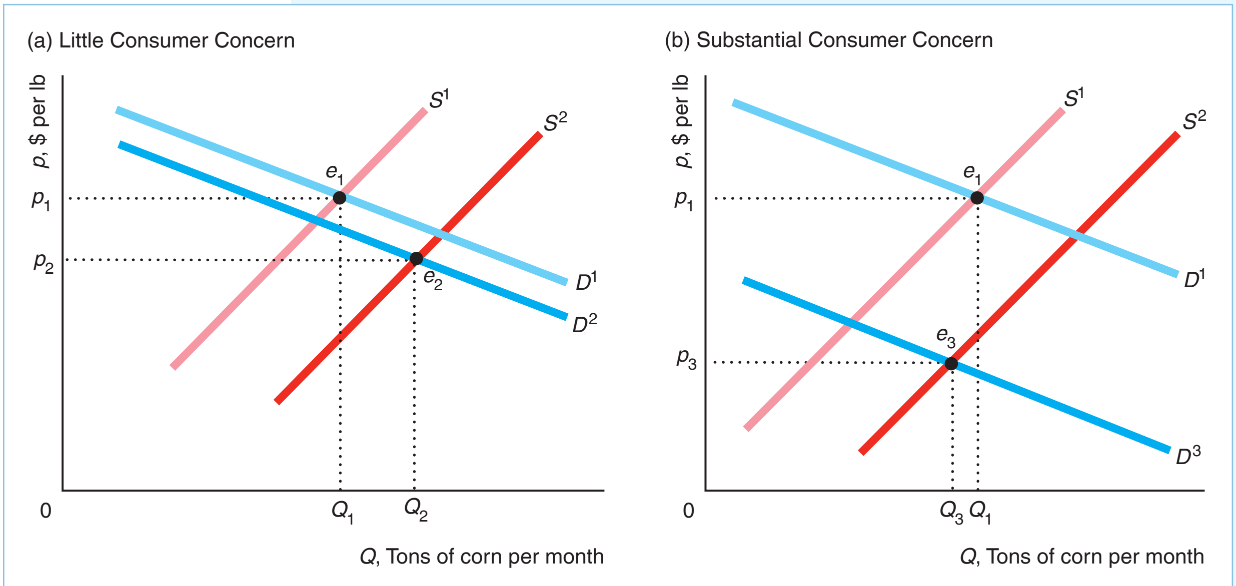
Quantities and Prices of Genetically Modified Foods

We conclude this chapter by returning to the Challenge posed at the beginning of the chapter, where we asked about the effects on the price and quantity of a crop, such as corn, from the introduction of GM seeds. The supply curve shifts to the right because GM seeds produce more output than traditional seeds, holding all else constant. If consumers fear GM products, the demand curve for corn shifts to the left. We want to determine how the after-GM equilibrium compares to the before-GM equilibrium. When an event shifts both curves, the qualitative effect on the equilibrium price and quantity may be difficult to predict, even if we know the direction in which each curve shifts. Changes in the equilibrium price and quantity depend on exactly how much the curves shift. In our analysis, we consider the possibility that the demand curve may shift only slightly in some countries where consumers don't mind GM products but substantially in others where many consumers fear GM products.

In the figure, the original, before-GM equilibrium, e_1, is determined by the intersection of the before-GM supply curve, S^1, and the before-GM demand curve, D^1, at price p_1 and quantity Q_1. Both panels a and b of the figure show this same equilibrium.

When GM seeds are introduced, the new supply curve, S^2, lies to the right of S^1. In panel a, the new demand curve, D^2, lies only slightly under D^1, while in panel b, D^3 lies substantially below D^1. In panel a, the new equilibrium e_2 is determined by the intersection of S^2 and D^2. In panel b, the new equilibrium e_3 reflects the intersection of S^2 and D^3.

The equilibrium price falls from p_1 to p_2 in panel a and to p_3 in panel b. However, the equilibrium quantity rises from Q_1 to Q_2 in panel a, but falls from Q_1 to Q_3 in panel b. Thus, when both curves shift, we can predict the direction of change of the equilibrium price, but cannot predict the change in the equilibrium quantity without knowing how much each curve shifts. Whether growers in a country decide to adopt GM seeds turns crucially on how resistant consumers are to these new products.



SUMMARY

1. **Demand.** The quantity of a good or service demanded by consumers depends on their tastes, the price of a good, the price of goods that are substitutes and complements, consumers' income, information, government regulations, and other factors. The *Law of Demand*—which is based on observation—says that *demand curves slope downward*. The higher the price, the less quantity is demanded, holding constant other factors that affect demand. A change in price causes a *movement along the demand curve*. A change in income, tastes, or another factor that affects demand other than price causes a *shift of the demand curve*. To derive a total demand curve, we horizontally sum the demand curves of individuals or types of consumers or countries. That is, we add the quantities demanded by each individual at a given price to determine the total quantity demanded.

2. **Supply.** The quantity of a good or service supplied by firms depends on the price, the firm's costs, government regulations, and other factors. The market supply curve need not slope upward but it usually does. A change in price causes a *movement along the supply curve*. A change in the price of an input or government regulation causes a *shift of the supply curve*. The total supply curve is the horizontal sum of the supply curves for individual firms.

3. **Market Equilibrium.** The intersection of the demand curve and the supply curve determines the equilibrium price and quantity in a market. Market forces—actions of consumers and firms—drive the price and quantity to the equilibrium levels if they are initially too low or too high.

4. **Shocking the Equilibrium: Comparative Statics.** A change in an underlying factor other than price causes a shift of the supply curve or the demand curve, which alters the equilibrium. Comparative statics is the method that economists use to analyze how variables controlled by consumers and firms—such as price and quantity—react to a change in *environmental variables*, such as prices of substitutes and complements, income, and prices of inputs.

5. **Elasticities.** An elasticity is the percentage change in a variable in response to a given percentage change in another variable, holding all other relevant variables constant. The price elasticity of demand, ε, is the percentage change in the quantity demanded in response to a given percentage change in price: A 1% increase in price causes the quantity demanded to fall by ε%. Because demand curves slope downward according to the Law of Demand, the elasticity of demand is always negative. The price elasticity of supply, η, is the percentage change in the quantity supplied in response to a given percentage change in price. Given estimated elasticities, we can forecast the comparative statics effects of a change in taxes or other variables that affect the equilibrium.

6. **Effects of a Sales Tax.** The two common types of sales taxes are ad valorem taxes, by which the government collects a fixed percentage of the price paid per unit, and specific taxes, by which the government collects a fixed amount of money per unit sold. Both types of sales taxes typically raise the equilibrium price and lower the equilibrium quantity. Also, both usually raise the price consumers pay and lower the price suppliers receive, so consumers do not bear the full burden or incidence of the tax. The effects on quantity, price, and the incidence of the tax that falls on consumers depend on the demand and supply elasticities. In competitive markets, the impact of a tax on equilibrium quantities, prices, and the incidence of the tax is unaffected by whether the tax is collected from consumers or producers.

7. **Quantity Supplied Need Not Equal Quantity Demanded.** The quantity supplied equals the quantity demanded in a competitive market if the government does not intervene. However, some government policies—such as price floors or ceilings—cause the quantity supplied to be greater or less than the quantity demanded, leading to persistent excesses or shortages.

8. **When to Use the Supply-and-Demand Model.** The supply-and-demand model is a powerful tool to explain what happens in a market or to make predictions about what will happen if an underlying factor in a market changes. However, this model is applicable only in competitive markets—markets with many buyers and sellers, in which firms sell identical goods, participants have full information, transaction costs are low, and firms can easily enter and exit.

EXERCISES

If you ask me anything I don't know, I'm not going to answer. —Yogi Berra

All exercises are available on MyLab Economics * = *answer appears at the back of this book;* **M** = *mathematical problem.*

1. Demand

*1.1 Suppose that the demand function for milled rice in India is $Q = 17 - 3p + 5p_w + 6p_m + 0.1Y$, where Q is the quantity in millions of tons of rice per year, p is the price of milled rice in thousands of rupees per ton, p_w is the price of wheat in thousands of rupees per ton, p_m is the price of maize in thousands of rupees per ton, and Y is average annual income in thousands of rupees. What is the demand curve if $p_w = 11$, $p_m = 11$, and $Y = 384$? **M**

*1.2 Using the demand function for milled rice from Question 1.1, show how the quantity demanded at a given price changes if per capita income, Y, increases by 10,000 rupees. **M**

1.3 Given an estimated demand function for avocados of $Q = 104 - 40p + 20p_t + 0.01Y$, show how the demand curve shifts as per capita income, Y, increases from \$4,000 to \$5,000 per month. (*Note*: The price of tomatoes, p_t, is \$0.80.) Illustrate this shift in a diagram. **M**

*1.4 Suppose that the demand function for movies is $Q_1 = 120 - p$ for college students and $Q_2 = 60 - 0.5p$ for other town residents. What is the town's total demand function ($Q = Q_1 + Q_2$ as a function of p)? Carefully draw a figure to illustrate your answer. **M**

1.5 Soybean oil is sold directly to consumers and used as an ingredient in a wide variety of processed foods. Soybean meal, the residue from producing soybean oil, is used as animal feed. Suppose the demand curves for soybean oil and soybean meal in Brazil are $Q_{oil} = 17 - 4p$ and $Q_{meal} = 27.9 - 10p$, respectively. What is the equation for the total demand curve and the total quantity demanded at a price of 1.6 thousand reals? (Hint: Review the Application "Aggregating Corn Demand Curves.") **M**

1.6 Based on information in the Application "The Demand Elasticities for Google Play and Apple Apps," the demand function for mobile applications at the Apple App Store is $Q_A = 1.4p^{-2}$ and the demand function at Google Play is $1.4p^{-3.7}$, where the quantity is in millions of apps. What is the total demand function for both firms? If the price for an app is \$1, what is the equilibrium quantity demanded by Apple customers, Google customers, and all customers? (*Hint*: Look at the Application "Aggregating Corn Demand Curves.") **M**

2. Supply

2.1 Suppose that the supply function for milled rice in India is $Q = 8 + 9p - 12p_r$, where Q is the quantity in millions of tons of rice per year, p is the price of milled rice in thousands of rupees per ton, and p_r is the price of rough rice in thousands of rupees per ton. How does the supply curve change if the price of rough rice increases from 12,000 to 20,000 rupees per ton? **M**

2.2 Given an estimated supply function for dairy cows milk production in Jordan, $lnQ_m = 1.304 + 0.564lnP_m + 1.754lnQ_c - 0.241lnP_c - 0.885lnC_v$, determine how much the supply curve shifts if the price of a dairy cow, P_C, decreases from JOD2,150 to JOD1,750. **M**

2.3 If the supply curve for fresh oranges in Egypt is $Q_e = 0.7 + 5p$ and the supply curve for fresh oranges for the rest of the world is $Q_{row} = 38.2 + 10p$, what is the world supply curve? **M**

*2.4 Various governments have, from time to time, set limits on how much of certain goods produced in other countries may be imported and sold domestically. Such quotas say that no more than $\overline{Q} > 0$ units of a particular targeted good may be imported into the country. Suppose both the domestic supply curve for a good, S_d, and the foreign supply curve for the same good for domestic sale, S_f, are upward sloping straight lines. How would a quota set by the country on foreign imports of $\overline{Q}$ affect that country's total supply curve for the good (domestic and foreign supply combined)?

2.5 A cartoon in this chapter shows two people in front of a swimming pool discussing whether they want to go swimming. How does colder weather in the winter affect the desire of people to go swimming? Does it cause a movement along the demand curve or a shift of the demand curve? Use a figure to illustrate your answer.

3. Market Equilibrium

*3.1 Use a supply-and-demand diagram to explain the statement "Talk is cheap because supply exceeds demand." At what price is this comparison being made?

3.2 If the demand function is $Q = 110 - 20p$, and the supply function is $Q = 20 + 10p$, what are the equilibrium price and quantity? **M**

*3.3 Suppose that the supply function for copra (dried coconut meat) for processing into coconut oil in the Philippines is $ln\,Q = 0.2 + 0.22\,ln\,p$, where Q is the quantity of copra in millions of tons per year and p is the price of copra in thousands of pesos per ton. If the demand function for copra for processing into coconut oil is $ln\,Q = 1.5 - 0.22\,ln\,p + 0.09\,ln\,p_0$, where $p_0 = 65$ is the price of coconut oil in thousands of pesos per ton in 2016, what is the demand curve for copra for processing? Solve for the equilibrium price and quantity of copra for processing into coconut oil (round your responses to one decimal place). **M**

3.4 The demand function for milled rice in India in Question 1.1 is $Q = 17 - 3p + 5p_w + 6p_m + 0.1Y$ and the supply function in Question 2.1 is $Q = 8 + 9p - 12p_r$. Solve for the equilibrium price and quantity in terms of the price of wheat, p_w, the price of maize, p_m, and average annual income, Y. If $p_w = 11$ (thousand rupees per ton), $p_m = 11$ (thousand rupees per ton), $p_r = 12$ (thousand rupees per ton), and $Y = 384$ (thousands of rupees), what are the equilibrium price and quantity? (Round your responses to one decimal place.) **M**

3.5 The demand function for a good is $Q = a - bp$, and the supply function is $Q = c + ep$, where a, b, c, and e are positive constants. Solve for the equilibrium price and quantity in terms of these four constants.

4. Shocking the Equilibrium: Comparative Statics

*4.1 Use a figure to explain the fisher's comment about the effect of a large catch on the market price in the cartoon about catching lobsters in this chapter. What is the supply shock?

4.2 The coronavirus pandemic caused the European natural gas demand curve to shift left by an estimated 7% (IEA (2020), Gas 2020, IEA, Paris https://www.iea.org/reports/gas-2020). Use a supply-and-demand diagram to show the likely effect on price and quantity (assuming that the market is competitive). Indicate the magnitude of the likely equilibrium price and quantity effects—for example, would you expect equilibrium quantity to change by about 7%? Show how the answer depends on the shape and location of the supply and demand curves.

4.3 Production of ethanol in the European Union (EU), primarily from wheat, increased more than 2.4 times from 570 million gallons in 2007 to 1,387 million gallons in 2015 (http://www.ethanolrfa.org/pages/statistics). In a supply-and-demand model of the market for wheat in the EU, how would this increased use of wheat for producing ethanol affect the price of wheat and the consumption of wheat as food, and why?

*4.4 The demand function is $Q = 220 - 2p$, and the supply function is $Q = 20 + 3p - 20r$, where r is the rental cost of capital. How do the equilibrium price and quantity vary with r? (*Hint*: See Solved Problem 2.1.) **M**

4.5 Recessions lower incomes and reduce rental prices for beachfront properties. Suppose that the demand function for renting a beachfront property in Barcelona, Spain, during the first week of August is $Q = 1{,}000 - p + Y/20$, where Y is the median annual income of the people involved in this market, Q is quantity, and p is the rental price. The supply function is $Q = 2p - Y/20$.

a. Derive the equilibrium price, p, and quantity, Q, in terms of Y.

b. Use a supply-and-demand analysis to show the effect of decreased income on the equilibrium price of rental homes. That is, find $\mathrm{d}p/\mathrm{d}Y$. Does a decrease in median income lead to a decrease in the equilibrium rental price? (*Hint*: See Solved Problem 2.1.) **M**

4.6 Colchero et al (2015) estimated the price elasticity of demand for sugar-sweetened beverages (SSB) in Mexico to be -1.16. Assume that in Mexico City, the annual per capita demand of SSB is given by $Q_D = 2750P^{-1.16}$ and that the market supply curve of SSBs is a horizontal line at a price, p, which equals $1.5p_w$, where p_w is the wholesale price of SSBs. (That is, retailers sell these beverages if they receive a price that is 50% higher than what they pay for the beverages to cover their other costs.)

a. Assuming a competitive market for sugar-sweetened beverages in Mexico City, calculate the equilibrium price and quantity of these beverages as a function of the wholesale price, p_w. If the equilibrium retail price is 10 pesos per liter, what is the wholesale price and quantity of beverages consumed?

b. Concerned about the health of its citizens, in 2014 the Mexican government introduced an excise tax of one peso per liter on all SSBs. Using both math and a graph, show how the introduction of the tax shifts the market supply curve. How does the introduction of the tax affect the equilibrium retail price and quantity of SSBs?

c. Health experts worry that despite the tax, Mexicans still consume too much sugary drinks. How large does the excise tax need to be, to limit the SSB consumption to 140 liters per person per year? **M**

*4.7 Given the answer to Exercise 2.4, what effect does a quota of $\overline{Q} > 0$ have on the equilibrium in the market? (*Hint*: The answer depends on whether the quota *binds*: is low enough to affect the equilibrium.)

4.8 Suppose the demand function for carpenters is $Q = 100 - w$, and the supply curve is $Q = 10 + 2w - T$, where Q is the number of carpenters, w is the wage, and T is the test score required to pass the licensing exam (which one must do to be able to work as a carpenter). By how much do the equilibrium quantity and wage vary as T increases? **M**

4.9 Use a figure to illustrate the wage (price) and quantity effects of the opioid as described in the Application "The Opioid Epidemic's Labor Market Effects."

4.10 Use calculus to illustrate how increased use of opioids, O, affects the equilibrium quantity of labor, L, as described in the Application "The Opioid Epidemic's Labor Market Effects," $\mathrm{d}L/\mathrm{d}O$. The labor demand function is $L = D(w)$, where L is the hours of work demanded and w is the wage. The labor supply function is $L = S(w, O)$, where L is the hours of work supplied. **M**

4.11 The Aguiar et al. (2017) study concluded that a revolution in the video game market—better games at a lower price—dramatically increased the amount of time young men spend playing video games and shifted their labor supply curve. In 2015, young men played video games for 3.4 hours per week on average. From 2000 through 2015, average annual hours of work for men aged 21–30, excluding full-time students, dropped by 12%. Suppose the labor demand function is $L = 200 - w$, and the supply curve is

$L = 40 + w - 2V$, where L is the hours worked, w is the wage, and V is a measure of the quality of video games. By how much do the equilibrium hours and wage vary as V increases? **M**

4.12 Bentonite clay, which consists of ancient volcanic ash, is used in kitty litter, to clarify wine, and for many other uses. One of the major uses is for drilling mud, a material pumped down oil and gas wells during drilling to keep the drilling bit cool. When oil drilling decreases, less bentonite is demanded at any given price. The price of crude oil was about \$50 a barrel in 2016–2017. However, by 2018, it was over \$70, causing drilling to increase. Use a supply-and-demand diagram to show the effect on the bentonite market and explain in words what happened.

5. Elasticities

5.1 According to the World Health Organization, the number of countries with tax shares representing more than 75% of the retail price of the most popular brand of cigarettes increased significantly between 2008 and 2012. If raising tobacco taxes to increase prices by 10% reduces tobacco use by 4% in high-income countries, and by 5% in low and middle-income countries, as the World Health Organization has suggested, what is the elasticity of demand for tobacco use in those countries? **M**

5.2 Calculate the elasticity of demand, if the demand function is

a. $Q = 120 - 2p + 4Y$, at the point where $p = 10$, $Q = 20$. (*Hint*: See Solved Problem 2.2.)

b. $Q = 10p^{-2}$. (*Hint*: See Solved Problem 2.3.) **M**

5.3 Based on information in the Application "The Demand Elasticities for Google Play and Apple Apps," the demand function for mobile applications at the Apple App Store is $Q_A = 1.4p^{-2}$ and the demand function at Google Play is $1.4p^{-3.7}$, where the quantity is in millions of apps. These demand functions are equal (cross) at one price. Which one? What are the elasticities of demand on each demand curve where they cross? Explain. (*Hint*: You can answer the last problem without doing any calculations. See Solved Problem 2.3.) **M**

5.4 When a disease like bovine spongiform encephalopathy (mad cow disease) is found, export markets for a country's beef products close down so that the supply for the domestic market increases in the short run. If the price for domestic beef falls by 1.6% for every 1% increase in supply, by how much would the domestic market price change if domestic supplies increase by 10.4%? Thinking as well about household consumption of beef products, can you expect an even larger change in the price of beef in the short run? **M**

5.5 According to Borjas (2003), immigration to the United States increased the labor supply of working men by 11.0% from 1980 to 2000, and reduced the wage of the average native worker by 3.2%. From these results, can we make any inferences about the elasticity of supply or demand? Which curve (or curves) changed, and why? Draw a supply-and-demand diagram and label the axes to illustrate what happened.

5.6 The World Health Organization has found that youth are more responsive than adults to tobacco tax increases (http://www.who.int/tobacco/economics/meetings/dublin_demand_for_tob_feb2012.pdf). If a 5% increase in the price of cigarettes causes cigarette consumption by youth to fall by 3.2%, what is their elasticity of demand for cigarettes? Is the demand for cigarettes by youth elastic or inelastic? **M**

5.7 In July 2012 a group of airline operators in the United Kingdom commissioned PricewaterhouseCoopers LLP (PwC) to estimate the impact of Air Passenger Duty (APD) on the economy of the United Kingdom. The study found that full abolition of the APD would increase demand for flights by 10%. If the average price of a ticket from London to Madrid route is £91, of which £13 is APD, what would the price elasticity of demand need to be for the statement above to be accurate? Assuming 100% cost pass-through, do you find this figure plausible? What if the cost pass-through is less than 100%? **M**

*5.8 Calculate the price and cross-price elasticities of demand for coconut oil. The coconut oil demand function (Buschena and Perloff, 1991) is $Q = 1{,}200 - 9.5p + 16.2p_p + 0.2Y$, where Q is the quantity of coconut oil demanded in thousands of metric tons per year, p is the price of coconut oil in cents per lb, p_p is the price of palm oil in cents per lb, and Y is the income of consumers. Assume that p is initially 45¢ per lb, p_p is 31¢ per lb, and Q is 1,275 thousand metric tons per year. **M**

5.9 Show that the supply elasticity of a linear supply curve that cuts the price axis is greater than 1 (elastic), and the coefficient of elasticity of any linear supply curve that cuts the quantity axis is less than 1 (inelastic). (*Hint*: See Solved Problem 2.4.) **M**

5.10 Solved Problem 2.5 claims that a new war in the Persian Gulf could shift the world oil supply curve to the left by 24 million barrels a day or more, causing the world price of oil to soar regardless of whether we drill in the Arctic National Wildlife Refuge (ANWR). How accurate is this claim? Use the same type of analysis as in the Solved Problem to calculate how much such a shock would cause the price to rise with and without the refuge production. **M**

5.11 In 2018, President Trump proposed opening nearly all offshore water to oil and gas drilling. The Bureau of Ocean Energy Management, which oversees government offshore leasing, estimated that President Trump's plan could eventually result in 21 billion barrels being economically recoverable.

6. Effects of a Sales Tax

6.1 What effect does a $1 specific tax have on equilibrium price and quantity, and what is the incidence on consumers, if the following is true:

a. The demand curve is perfectly inelastic.

b. The demand curve is perfectly elastic.

c. The supply curve is perfectly inelastic.

d. The supply curve is perfectly elastic.

e. The demand curve is perfectly elastic and the supply curve is perfectly inelastic.

Use graphs and math to explain your answers. (*Hint*: See Solved Problem 2.6.) **M**

6.2 If a tax is introduced and the full burden or incidence of the tax is borne by consumers, what can we say about the shape of the market supply and demand curves, or the demand and supply elasticities? Use graphs to illustrate your answer.

6.3 If a tax is introduced and the full burden or incidence of the tax is borne by producers, what can we say about the shape of the market supply and demand curves, or the demand and supply elasticities? Use graphs to illustrate your answer. **M**

*6.4 Do you care whether a 15¢ tax per gallon of milk is collected from milk producers or from consumers at the store? Why or why not?

6.5 Green, Howitt, and Russo (2005) estimated that for almonds, the demand elasticity was −0.47 and the long-run supply elasticity was 12.0. The corresponding elasticities were −0.68 and 0.73 for cotton and −0.26 and 0.64 for processing tomatoes. If the government were to apply a specific tax to each of these commodities, what would be the consumer tax incidence for each of these commodities? **M**

6.6 Figure 2.12 shows the effects of a specific tax of $2.40 per unit on equilibrium price and quantity. What is the equation of demand curve, D^1, and supply curve, S^1? A subsidy is a negative tax. If the government applied a $2.40 specific subsidy (giving people money) instead of a specific tax (taking money away) in Figure 2.12, what would the effect be on equilibrium price and quantity? Use the demand and supply curves to solve for the new equilibrium values. What is the incidence of the subsidy on consumers? **M**

6.7 Canada provided a 35% subsidy of the wage of video game manufacturers' employees in 2011.

a. What is the effect of a wage subsidy on the equilibrium wage and quantity of workers?

b. What happens when the wage subsidy rate falls?

c. What is the incidence of the subsidy?

*6.8 Use calculus to show that the less elastic the demand curve, an increase in a specific sales tax t reduces quantity less and tax revenue more. (*Hint*: The quantity demanded depends on its price, which in turn depends on the specific tax, $Q(p(t))$, and tax revenue is $R = p(t)Q(p(t))$.) **M**

6.9 The United Kingdom had a drinking problem. British per capita consumption of alcohol rose 19% between 1980 and 2007, compared with a 13% decline in other developed countries. Worried about excessive drinking among young people, the British government increased the tax on beer by 42% from 2008 to 2012. Under what conditions will this specific tax substantially reduce the equilibrium quantity of alcohol? Answer in terms of the elasticities of the demand and supply curves.

6.10 The estimated demand function for coffee is $Q = 12 - p$ (Equation 2.3), and the estimated supply function is $Q = 9 + 0.5p$ (Equation 2.7).

a. Write equations for the equilibrium price and quantity as a function of a specific tax t.

b. What are the equilibrium price and quantity and the tax incidence on consumers if $t = \$0.75$? **M**

7. Quantity Supplied Need Not Equal Quantity Demanded

7.1 Severe disruptions to the supply of petroleum caused by international events or natural disasters can result in sharp spikes in prices within an economy for petroleum products such as gasoline. To keep gasoline prices from rising as much, the government may consider imposing a price ceiling on gasoline that is below the new equilibrium price. What effect would such a price ceiling have? Who would benefit, and who would be harmed by this policy? Use a supply and-demand diagram to illustrate your answers.

7.2 The Thai government actively intervenes in markets (Nophakhun Limsamarnphun, "Govt Imposes Price Controls in Response to Complaints," *The Nation*, May 12, 2012).

a. The government increased the daily minimum wage by 40% to Bt 300 ($9.63). Show the effect of a higher minimum wage on the number of workers demanded, the supply of workers, and unemployment if the law is applied to the entire labor market.