CHAPTER 3

Supply, Demand, and Elasticity

After reading this chapter, you will understand:

1. How the responsiveness of quantity demanded to a price change can be expressed in terms of elasticity.
2. How elasticity of demand is related to revenue.
3. How elasticity applies to changes in market conditions other than price.
4. How elasticity is useful in interpreting issues of taxation and other public policies.

Before reading this chapter, make sure you know the meaning of:

1. Supply and demand
2. Demand, quantity demanded
3. Supply, quantity supplied
4. Substitutes and complements
5. Normal and inferior goods

How much did you pay for this textbook? Was it more expensive or less expensive than the books you buy for other courses? As a student, you probably have a strong desire to pay less for your books if you can. Have you ever wondered why your professors sometimes choose books that are so expensive?

This chapter will help you understand the effect of price on choices that people make among alternative goods, like different textbooks, different foods, or different modes of transportation. It will focus on the concept of *elasticity*, a word economists use to say how sensitive such choices are to price. As a student, your choice of textbook is probably very sensitive to price—your demand is *elastic*, to use the economist's term. However, your professor, who does not pay for the books, cares less about how much they cost. Your professor's demand may be *inelastic*. In the following pages you will learn how to define, measure, and apply the important concept of elasticity.

ELASTICITY

The responsiveness of quantity demanded to a change in price can be expressed in many ways, depending on the units of measurement that are chosen. Consider the demand for chicken, an example used in the preceding chapter. A study of the budget of a single American household might find that an increase of ten cents per pound would decrease consumption by 1 pound per week. A study done in France might find that a price increase of 1 euro per kilogram decreased consumption of all consumers in the city of Lille by 25,000 kilos per month. Are the findings of these studies similar? It is hard to tell, because the units used are different. It would require more information, and some calculations, to know whether the sensitivity of demand to price as measured in different countries using different currencies, are the same. The same would be true of two studies in one country if one measured price in dollars per ton and tons per year, while the other used dollars per pound and pounds per week.

To avoid confusion arising from the choice of different units of measurement, it is useful to standardize. One common way of doing so is to express all changes as percentages. Suppose, for example, that the studies of both American and French consumers found that a 20 percent increase in price was associated with a 10 percent decrease in quantity demanded. These percentages would stay the same regardless of whether the original data were stated in dollars per pound, euros per kilo, or any other measurement.

The use of percentages to express the response of one variable to a change in another is widespread in economics. The term **elasticity** is used to refer to relationships expressed in percentages. Like equilibrium, elasticity is a metaphor borrowed from physics. Much as equilibrium calls to mind a pendulum that has come to rest hanging straight down, elasticity conjures up the image of a rubber band that stretches by a certain percentage of its length when the force applied to it is increased by a given percentage. This chapter introduces several applications of elasticity in economics.

Elasticity

A measure of the response of one variable to a change in another, stated as a ratio of the percentage change in one variable to the associated percentage change in another variable.

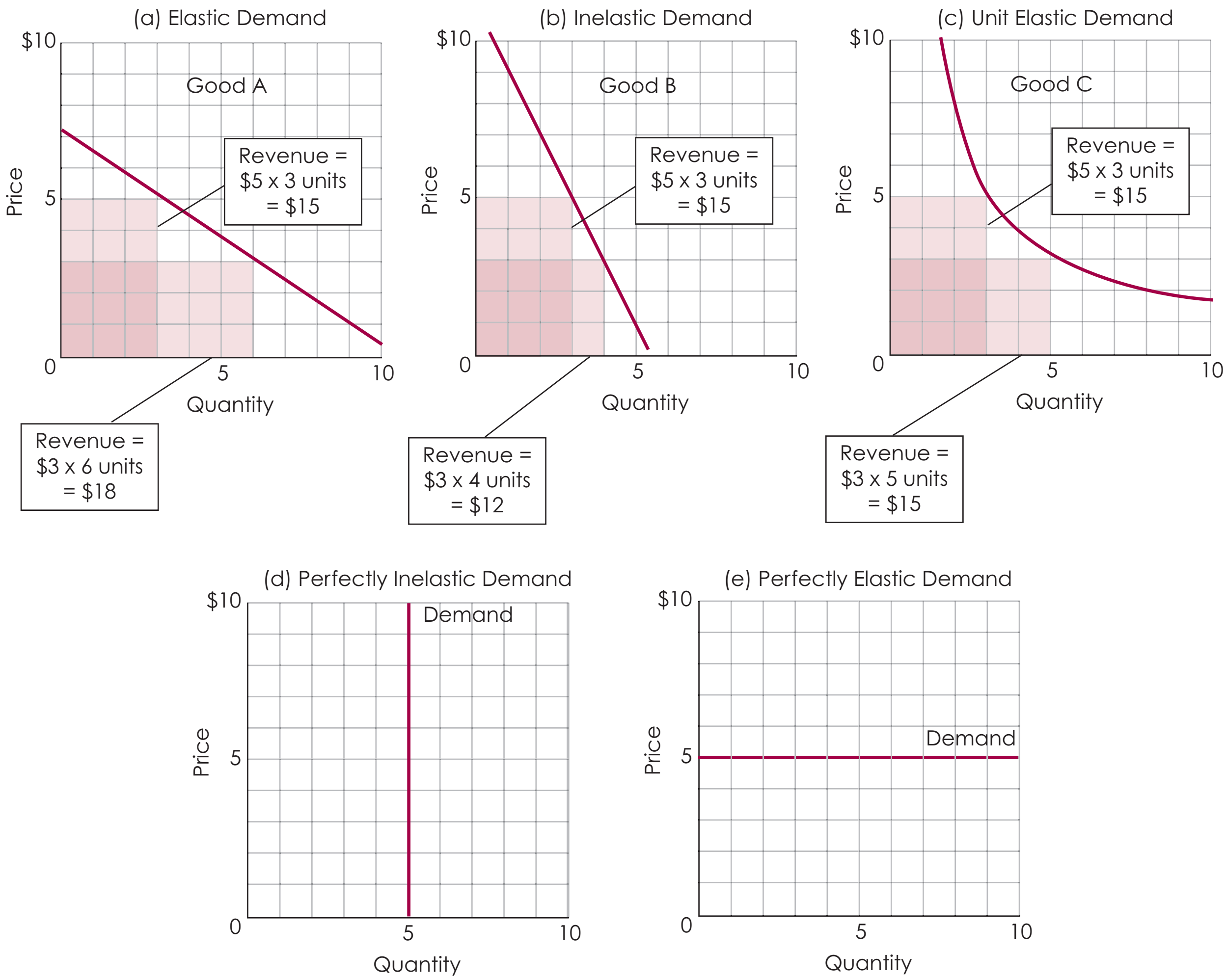
Price Elasticity of Demand

We begin with the relationship between price and quantity demanded. The **price elasticity of demand** is the ratio of the percentage change in the quantity of a good demanded to a given percentage change in its price. Figure 3.1 presents five demand curves showing different degrees of price elasticity of demand. In part (a), the quantity demanded is strongly responsive to a change in price. In this case, a decrease in price from \$5 to \$3 causes the quantity demanded to increase from three units to six.

Price elasticity of demand

The ratio of the percentage change in the quantity of a good demanded to a given percentage change in its price, other things being equal.

FIGURE 3.1 PRICE ELASTICITY OF DEMAND



This figure shows five examples of demand curves with various degrees of elasticity over the indicated range of variation of price and quantity. The examples illustrate elastic, inelastic, unit elastic, perfectly inelastic, and perfectly elastic demand. For the first three cases, the revenue change associated with a change in price is shown. When demand is elastic, a price decrease causes revenue to increase. When demand is inelastic, a price decrease causes revenue to decrease. When demand is unit elastic, revenue does not change when price changes.

Revenue

Price times quantity sold.

Changes in price and quantity are reflected in the **revenue** earned from sale of the product. Revenue means the price times the quantity sold. In part (a) of Figure 3.1, the percentage change in quantity demanded is greater than the percentage change in price, so the drop in price causes total revenue from sales of the good to increase. On a supply-and-demand diagram, revenue can be shown as the area of a rectangle drawn under the demand curve, with a height equal to price and a width equal to quantity demanded. In this case comparison of the shaded rectangles representing revenue before the price reduction ($5 per unit x 3 units = $15) and afterward ($3 per unit x 6

Elastic demand

A situation in which quantity demanded changes by a larger percentage than price, so that total revenue increases as price decreases.

Inelastic demand

A situation in which quantity demanded changes by a smaller percentage than price, so that total revenue decreases as price decreases.

Unit elastic demand

A situation in which price and quantity demanded change by the same percentage, so that total revenue remains unchanged as price changes.

Perfectly inelastic demand

A situation in which the demand curve is a vertical line.

Perfectly elastic demand

A situation in which the demand curve is a horizontal line.

units = $18) shows that revenue is greater after the price has been reduced. When the quantity demanded changes by a greater percentage than price, so that a price decrease causes total revenue to increase, demand is said to be **elastic**.

Part (b) of Figure 3.1 shows a case in which the quantity demanded is only weakly responsive to a change in price. Here, a $2 decrease in price, from $5 to $3 per unit, causes the quantity demanded to increase by just one unit—from three to four. This time the percentage change in quantity demanded is less than that in price. As a result, the decrease in price causes total revenue to fall (again note the shaded rectangles). In such a case demand is said to be **inelastic**.

Part (c) shows a case in which a change in price causes an exactly proportional change in quantity demanded, so that total revenue does not change at all. When the percentage change in quantity demanded equals the percentage change in price, demand is said to be **unit elastic**.

The final two parts of Figure 3.1 show two extreme cases. Part (d) shows a vertical demand curve. Regardless of the price, the quantity demanded is five units—no more, no less. Such a demand curve is said to be **perfectly inelastic**. Part (e) shows a demand curve that is perfectly horizontal. Above a price of $5, no units of the good can be sold; but as soon as the price drops to $5, there is no limit on how much can be sold. A horizontal demand curve like this one is described as **perfectly elastic**. The law of demand, which describes an inverse relationship between price and quantity, does not encompass the cases of perfectly elastic and inelastic demand, and we do not expect market demand curves for ordinary goods and services to fit these extremes. Nevertheless, we will see that perfectly elastic and inelastic curves sometimes provide useful reference points for theory building, even though they do not resemble real-world market demand curves.

Calculating Elasticity of Demand

In speaking of elasticity of demand, it is sometimes enough to say that demand is elastic or inelastic, without being more precise. At other times, it is useful to give a numerical value for elasticity. This section introduces the most common method used to calculate a numerical value for elasticity of demand.

The first step in turning the general definition of elasticity into a numerical formula is to develop a way to measure percentage changes. The everyday method for calculating a percentage change is to use the initial value of the variable as the denominator and the change in the value as the numerator. For example, if the quantity of California lettuce demanded in the national market is initially 10,000 tons per week and then decreases by 2,500 tons per week, we say that there has been a 25 percent decrease (2,500/10,000 = .25). The trouble with this convention is that the same change in the opposite direction gives a different percentage. By everyday reasoning, an increase in the quantity of lettuce demanded from 7,500 tons per week to 10,000 tons per week is a 33 percent increase (2,500/7,500 = .33).

Decades ago the mathematical economist R. G. D. Allen proposed an unambiguous measure of percentage changes that uses the midpoint of the range over which change takes place as the denominator. Allen's formula is not the only possible one, but it caught on and remains the most popular.

To find the midpoint of the range over which a change takes place, we take the sum of the initial value and the final value and divide by 2. In our example, the midpoint of the quantity range is (7,500 + 10,000)/2 = 8,750. When this is used as the denominator, a change of 2,500 units becomes (approximately) a 28.6 percent change (2,500/8,750 = .286). Using Q_1 to represent the quantity before the change and Q_2 to represent the quantity after the change, the midpoint formula for the percentage change in quantity is

$$\text{Percentage change in quantity} = \frac{Q_2 - Q_1}{(Q_1 + Q_2)/2}$$

The same approach can be used to define the percentage change in price. In our case, the price of lettuce increased from about \$250 per ton to about \$1,000 per ton. Using the midpoint of the range, or \$625, as the denominator [(\$250 + \$1,000)/2 = \$625], we conclude that the \$750 increase in price is a 120 percent increase (\$750/\$625 = 1.2). The midpoint formula for the percentage change in price is

$$\text{Percentage change in price} = \frac{P_2 - P_1}{(P_1 + P_2)/2}$$

THE MIDPOINT FORMULA FOR ELASTICITY Defining percentage changes in this way allows us to write a useful formula for calculating elasticities. With P_1 and Q_1 representing price and quantity before a change, and P_2 and Q_2 representing price and quantity after the change, the midpoint formula for elasticity is

$$\text{Price elasticity of demand} = \frac{(Q_2 - Q_1)/(Q_1 + Q_2)}{(P_2 - P_1)/(P_1 + P_2)} = \frac{\text{Percentage change in quantity}}{\text{Percentage change in price}}$$

Here is the complete calculation for the elasticity of demand for lettuce when an increase in price from \$250 per ton to \$1,000 per ton causes the quantity demanded to fall from 10,000 tons per day to 7,500 tons per day:

P_1 = price before change = \$250
P_2 = price after change = \$1,000
Q_1 = quantity before change = 10,000
Q_2 = quantity after change = 7,500

$$\text{Elasticity} = \frac{(7{,}500 - 10{,}000)/(7{,}500 + 10{,}000)}{(\$1{,}000 - \$250)/(\$1{,}000 + \$250)}$$

$$= \frac{-2{,}500/17{,}500}{\$750/\$1{,}250}$$

$$= \frac{-.142}{.6}$$

$$= -.24$$

Because demand curves have negative slopes, this formula yields a negative value for elasticity. The reason is that the quantity demanded changes in the direction opposite to that of the price change. When the price decreases, $(P_2 - P_1)$, which appears in the denominator of the formula, is negative, whereas $(Q_2 - Q_1)$, which appears in the numerator, is positive. When the price increases, the numerator is negative and the denominator is positive. However, in this book we follow the widely used practice of dropping the minus sign when discussing price elasticity of demand. Thus, the elasticity of demand for lettuce would be stated as approximately .24 over the range studied.

A numerical elasticity value such as .24 can be related to the basic definition of elasticity in a simple way. That definition stated that price elasticity of demand as the ratio of the percentage change in quantity demanded to a given percentage change in price. Thus, an elasticity of .24 means that the quantity demanded will increase by .24 percent for each 1 percent change in price. An elasticity of 3 would mean that quantity demanded would change by 3 percent for each 1 percent change in price, and so on.[1]

ELASTICITY VALUES AND TERMINOLOGY Earlier in the chapter we defined *elastic, inelastic, unit elastic, perfectly elastic,* and *perfectly inelastic* demand. Each of these terms corresponds to a numerical value or range of values of elasticity. A perfectly inelastic demand curve has a numerical value of 0, since any change in price produces no change in quantity demanded. The term *inelastic* (but not perfectly inelastic) *demand* applies to numerical values from 0 up to, but not including, 1. *Unit elasticity,* as the name implies, means a numerical value of exactly 1. *Elastic demand* means any value for elasticity that is greater than 1. *Perfectly elastic* demand, represented by a horizontal demand curve, is not defined numerically; as the demand curve becomes horizontal, the denominator of the elasticity formula approaches 0 and the numerical value of elasticity increases without limit.

Varying- and Constant-Elasticity Demand Curves

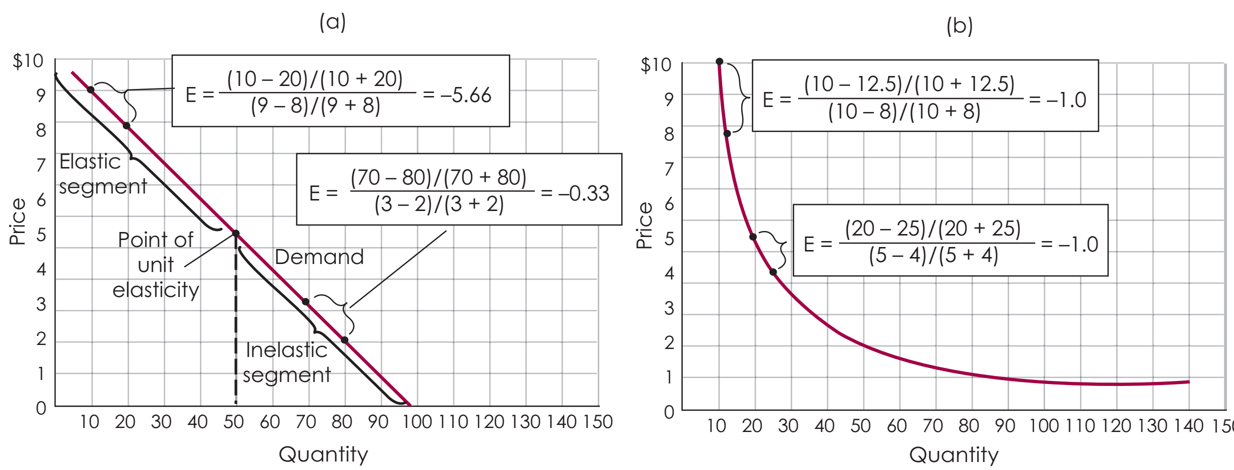
The midpoint formula shows elasticity of demand over a certain range of prices and quantities. Measured over some other range, the elasticity of demand for the same good may be the same or different, depending on the shape of the demand curve, as shown in Figure 3.2.

Part (a) of Figure 3.2 shows a demand curve that, like most of those in this book, is a straight line. The elasticity of demand is not constant for all ranges of price and quantity along this curve. For example, when measured over the price range $8 to $9, the elasticity of demand is 5.66; when measured over the range $2 to $3, it is .33. (The calculations are shown in the figure.)

The calculations illustrate the general rule that elasticity declines as one moves downward along a straight-line demand curve. It is easy to see why. With such a demand curve, a $1 reduction in price always causes the same absolute increase in quantity demanded. At the upper end of the demand curve, a $1 change is a small percentage of the relatively high price, while the change in quantity is a large percentage of the relatively low quantity demanded at that price. At the lower end of the curve, however, the situation is reversed: A $1 change is now a large percentage of the relatively low price, while the increase in quantity is smaller in relation to the relatively larger quantity demanded. Because it is percentages, not absolute amounts, that matter in elasticity calculations, a linear demand curve is less elastic near the bottom than near the top.

If the demand curve is not a straight line, other results are possible. There is an important special case in which the demand curve has just the curvature needed to keep elasticity constant over its entire length. Such a curve is shown in part (b) of Figure 3.2. As can be seen from the calculations in the figure, elasticity is 1.0 at every

FIGURE 3.2 ELASTICITY AT VARIOUS POINTS ALONG A DEMAND CURVE



Elasticity varies along a straight-line demand curve, as part (a) of this figure illustrates. At the upper end of the curve, where the price is relatively high, a $1 change in price is a relatively small percentage change, and, because the quantity demanded is low, the corresponding change in quantity is relatively large in percentage terms. Demand is thus elastic near the top of the demand curve. At the lower end of the curve, the situation is reversed: a $1 change in price is now a relatively large change in percentage terms, whereas the corresponding change in quantity is smaller in percentage terms. Thus demand is inelastic. As part (b) shows, a curved demand curve can be drawn such that elasticity is constant for all ranges of price and quantity change.

point on that curve. It is possible to construct demand curves with constant elasticities of any value. Econometric studies of demand elasticity often look for the constant-elasticity demand curve that most closely approximates buyers' average sensitivity to price changes as revealed by market data over time.

Determinants of Elasticity of Demand

The fact that elasticity often varies along the demand curve means that care must be taken in making statements about the elasticity of demand for a good. In practice, what such statements usually refer to is the elasticity, measured by the midpoint formula or some alternative method, over the range of price variation that is commonly observed in the market for that good. With this understanding, we can make some generalizations about what makes the demand for some goods elastic and the demand for others inelastic.

SUBSTITUTES, COMPLEMENTS, AND ELASTICITY One important determinant of elasticity of demand is the availability of substitutes. When a good has close substitutes, the demand for that good tends to be elastic, because people willingly switch to the substitutes when the price of the good goes up. Thus, for example, the demand for corn oil is elastic because other cooking oils can usually be substituted for it. On the other hand, the demand for cigarettes is inelastic because for a habitual smoker there is no good substitute.

This principle has two corollaries. One is that the demand for a good tends to be more elastic the more narrowly the good is defined. For example, the demand for lettuce in the numerical example given earlier was inelastic. This could be because many people are in the habit of eating a salad with dinner and do not think of spinach or coleslaw as completely satisfactory substitutes. At the same time, however, it could be that the demand for any particular variety of lettuce is elastic. If the price of Boston lettuce rises while the prices of iceberg, romaine, and red-leaf lettuce remain unchanged, many people will readily switch to one of the other varieties, which they see as close substitutes.

The other corollary is that demand for the product of a single firm tends to be more elastic than the demand for the output of all producers operating in the market. As one example, the demand for cigarettes as a whole will be less elastic than the demand for any particular brand. The reason is that one brand can be substituted for another when the price of a brand changes.

The complements of a good can also play a role in determining its elasticity. If something is a minor complement to an important good (that is, one that accounts for a large share of consumers' budgets), demand for it tends to be inelastic. For example, the demand for motor oil tends to be inelastic because it is a complement to a more important good, gasoline. The price of gasoline has a greater effect on the amount of driving a person does than the price of motor oil.

PRICE VS. OPPORTUNITY COST Elasticity measures the responsiveness of quantity demanded to the monetary price of a good. In most cases, the price, in money, is an accurate approximation of the opportunity cost of choosing a good, but that is not always the case. We mentioned one example at the beginning of the chapter: The price of a textbook is an opportunity cost to the student who buys it, but it is not an opportunity cost to the professor who assigns it, because the students pay for the book, not the professor. As a result, publishers have traditionally assumed that professors will pay little attention to the price of the text, and demand will be highly inelastic. However, in recent years students have increasingly been making their influence felt, so that price-elasticity of demand for textbooks may be increasing.

The textbook market is a relatively small one, but there are other much more important markets where the responsibility for choice does not lie with the party who bears the opportunity cost. Medical care provides many examples. Doctors choose what drug to offer to patients, but either the patient or the patient's insurance company pays for the drug. As a result, demand for drugs is very inelastic, and doctors sometimes prescribe expensive brand-name drugs when cheaper generic drugs are available to do the same job.

Business travel is still another example of the separation of price and opportunity cost. Business travelers do not pay for their own airline tickets, hotels, and meals, so their demand for these services tends to be inelastic. When vacationers purchase the same services, they bear the full opportunity cost themselves. Not surprisingly, business travelers often choose more expensive options. In many cases airlines and hotels take advantage of the separation of price and opportunity cost by charging different rates to business and vacation travelers.

TIME HORIZON AND ELASTICITY One of the most important considerations determining the price elasticity of demand is the time horizon within which the decision to buy is made. For several reasons, demand is often less elastic in the short run than in the long run.

One reason is that full adjustment to a change in the price of a good may require changes in the kind or quantity of many other goods that a consumer buys. Gasoline provides a classic example. When the price of gasoline jumped in the early 2000s, many people's initial reaction was to cut out some nonessential driving, but the total quantity of gasoline demanded was not much affected. As time went by, though, consumers began adjust in many ways. One important adjustment, as mentioned in Chapter 1, was to buy fewer fuel-hungry SUVs and more higher-mileage cars. If this trend continues, the total amount of gasoline purchased could fall substantially.

Another reason elasticity tends to be greater in the long run than in the short run is that an increase in the price of one good encourages entrepreneurs to develop substitutes, which, as we have seen, can be an important determinant of elasticity. To take an example from history, consider the response to what has been called America's first energy crisis: a sharp increase in the price of whale oil, which was used as lamp fuel in the early nineteenth century. At first candles were the only substitute for whale-oil lamps, and not a very satisfactory one. People therefore cut their use of whale oil only a little when the price began to rise, but the high price of whale oil spurred entrepreneurs to develop a better substitute, kerosene. Once kerosene came onto the market, the quantity of whale oil demanded for use as lamp fuel dropped to zero.

A final reason for greater elasticity of demand in the long run than in the short run is the slow adjustment of consumer tastes. The case of beef and chicken, featured in the preceding chapter, provides an example. Chicken, originally the more expensive meat, achieved a price advantage over beef many years ago, but eating lots of beef was a habit. Gradually, though, chicken developed an image as a healthy, stylish, versatile food, and finally it overtook beef as the number-one meat in the United States.

Income Elasticity of Demand

Determining the response of quantity demanded to a change in price is the most common application of the concept of elasticity, but it is by no means the only one. Elasticity can also be used to express the response of demand to any of the conditions covered by the "other things being equal" assumption on which a given demand curve is based. As we saw in the preceding chapter, consumer income is one of those conditions.

Income elasticity of demand

The ratio of the percentage change in the quantity of a good demanded to a given percentage change in consumer incomes, other things being equal.

The **income elasticity of demand** for a good is defined as the ratio of the percentage change in the quantity of that good demanded to a percentage change in income. In measuring income elasticity, it is assumed that the good's price does not change. Using Q_1 and Q_2 to represent quantities before and after the change in income, and y_1 and y_2 to represent income before and after the change, the midpoint formula for income elasticity of demand can be written as follows:

$$\text{Income elasticity of demand} = \frac{(Q_2 - Q_1)/(Q_1 + Q_2)}{(y_2 - y_1)/(y_1 + y_2)} = \frac{\text{Percentage change in quantity}}{\text{Percentage change in income}}$$

For a normal good, an increase in income causes demand to rise. Because income and demand change in the same direction, the income elasticity of demand for a normal good is positive. For an inferior good, an increase in income causes demand to decrease. Because income and demand change in opposite directions, the income elasticity of demand for an inferior good is negative.

Some of the considerations that determine price elasticity also affect income elasticity. In particular, whether a good is considered to be normal or inferior depends on how narrowly it is defined and on the availability of substitutes. For example, a study by Jonq-Ying Lee, Mark G. Brown, and Brooke Schwartz of the University of Florida looked at the demand for frozen orange juice.[2] Orange juice considered as a broad category is a normal good; people tend to consume more of it as their income rises. However, when the definition is narrowed so that house-brand and national-brand frozen orange juice are treated as separate products, the house-brand product turns out to be an inferior good. As their incomes rise, consumers substitute the higher-quality national brands, which have a positive income elasticity of demand.

Cross-Elasticity of Demand

Cross-elasticity of demand

The ratio of the percentage change in the quantity of a good demanded to a given percentage change in the price of some other good, other things being equal.

Another condition that can cause a change in the demand for a good is a change in the price of some other good. The demand for chicken is affected by changes in the price of beef, the demand for SUVs by changes in the price of gasoline, and so on. The **cross-elasticity of demand** for a good is defined as the ratio of the percentage change in the quantity of that good demanded to a given percentage change in the price of another good. The midpoint formula for cross-elasticity of demand looks just like the one for price elasticity of demand, except that the numerator shows the percentage change in the quantity of one good while the denominator shows the percentage change in the price of some other good.

Cross-elasticity of demand is related to the concepts of substitutes and complements. Because lettuce and cabbage are substitutes, an increase in the price of cabbage causes an increase in the quantity of lettuce demanded; the cross-elasticity of demand is positive. Because SUVs and gasoline are complements, an increase in the price of gasoline causes a decrease in the quantity of SUVs demanded; the cross-elasticity of demand is negative. The previously mentioned study of frozen orange juice found a positive cross-elasticity of demand between house-brand and national-brand juices, indicating that the two are substitutes.

Price Elasticity of Supply

Price elasticity of supply

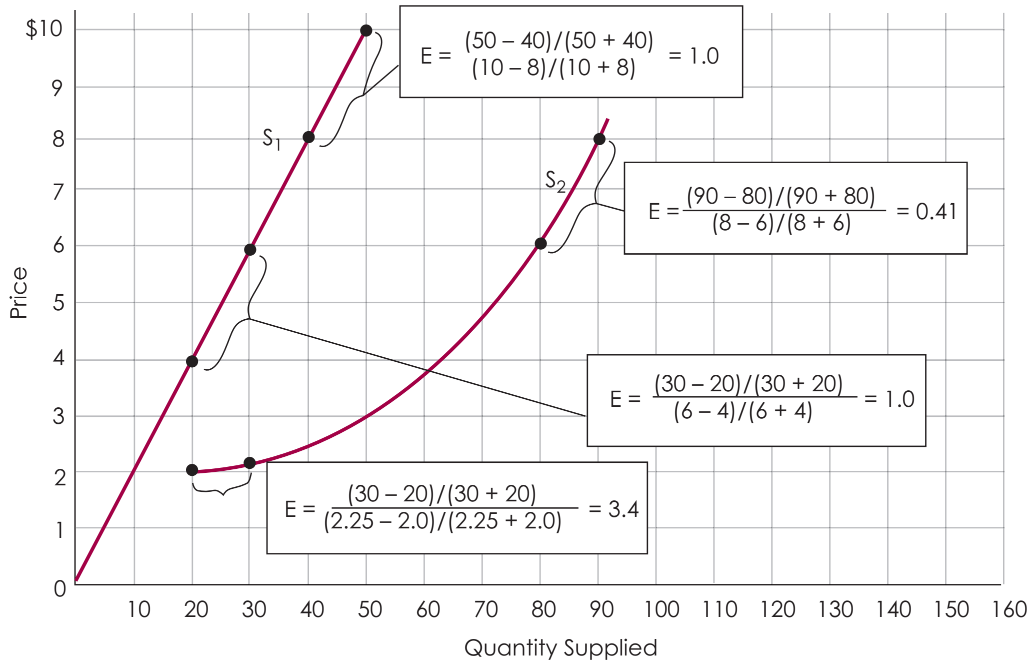
The ratio of the percentage change in the quantity of a good supplied to a given percentage change in its price, other things being equal.

Elasticity is not confined to demand; it can also be used to indicate the response of quantity supplied to a change in price. Formally, the **price elasticity of supply** of a good is defined as the percentage change in the quantity of the good supplied divided by the percentage change in its price. The midpoint formula for calculating price elasticity of supply looks like the one for determining price elasticity of demand, but the Qs in the numerator of the formula now refer to quantity *supplied* rather than quantity *demanded*. Because price and quantity change in the same direction along a positively sloped supply curve, the formula gives a positive value for the elasticity of supply. Figure 3.3 applies the elasticity formula to two supply curves, one with constant elasticity and the other with variable elasticity.

In later chapters we will look in detail at the considerations that determine the elasticity of supply for various products. Two of those considered are especially important, however, and deserve some discussion here.

One determinant of the elasticity of supply of a good is the mobility of the factors of production used to produce it. As used here, *mobility* means the ease with which factors can be attracted away from some other use, as well as the ease with which they can be reconverted to their original use. The trucking industry provides a classic example of mobile resources. As a crop such as lettuce or watermelons

FIGURE 3.3 CALCULATING PRICE ELASTICITY OF SUPPLY



This figure gives four examples of the way price elasticity of supply is calculated. Price elasticity of supply is shown for two ranges on each of the two supply curves. Supply curve S_1 which is a straight line passing through the origin, has a constant elasticity of 1.0. Supply curve S_2, which is curved, is elastic for small quantities and inelastic for larger ones.

comes to harvest in a particular region of a country, hundreds of trucks are needed to haul it to market. Shippers compete for available trucks, driving up the price paid to truckers in the local market. Independent truckers throughout the country learn—from their own experience, from trucking brokers, and from Internet sites—where they can earn the best rates for hauling produce. It takes only a modest rise in the price for hauling a load of Georgia watermelons to attract enough truckers to Georgia to haul the crop to market. When the harvest is over, the truckers will move elsewhere to haul peaches, tomatoes, or whatever.

In contrast, other products are produced with resources that are not so mobile. Petroleum provides a good example. When oil prices rise, producers have an incentive to drill more wells. However, given limited numbers of drilling rigs and other highly specialized equipment, not to mention limited numbers of sites worth exploring, even a doubling of oil prices has only a small effect on oil output. Factor mobility in this industry is limited in the other direction, too. Once a well has been drilled, the investment cannot be converted to a different use. Thus, when world demand falls, as it did in 1998, prices fall sharply but the quantity of oil produced falls by much less than price.

A second determinant of elasticity of supply is time. As in the case of demand, price elasticity of supply tends to be greater in the long run than in the short run. In part, the reason for this is connected with mobility of resources. In the short run, the output of many products can be increased by using more of the most flexible inputs—for example, by adding workers at a plant or extending the hours of work. Such short-run measures often mean higher costs per unit for the added output, however, because workers added without comparable additions in other inputs (such as equipment) tend to be less productive. If a firm expects market conditions to warrant an increase of supply in the long run, it will be worthwhile to invest in additional quantities of less mobile inputs such as specialized plants and equipment. Once those investments have been made, the firm will find it worthwhile to supply the greater quantity of output at a lower price than in the short-run case because its costs per unit supplied will be lower. The Case for Discussion at the end of Chapter 2, which discussed the market for heavy-duty tires, provides an example of the difference between short-run and long-run elasticity of supply.

APPLICATIONS OF ELASTICITY

Elasticity has many applications in both macro- and microeconomics. In macroeconomics, it can be applied to money markets, to the aggregate supply and demand for all goods and services, and to foreign-exchange markets, to name just a few. In microeconomics, elasticity plays a role in discussions of consumer behavior, the profit-maximizing behavior of business firms, governments' regulatory and labor policies, and many other areas. To further illustrate elasticity, we conclude this chapter with applications featuring the problems of tax incidence and drug policy.

Elasticity and Tax Incidence

Who pays taxes? One way to answer this question is in terms of *assessments*—the issue of who bears the legal responsibility to make tax payments to the government. A study of assessments would show that property owners pay property taxes, gasoline retailers pay gasoline taxes, and so on. However, looking at assessments does not always settle the issue of who bears the economic burden of a tax—or, to use the economist's term, the issue of **tax incidence**.

Tax incidence

The distribution of the economic burden of a tax.

The incidence of a tax does not always coincide with the way the tax is assessed, because the economic burden of the tax, in whole or in part, often can be passed along to someone else. The degree to which the burden of a tax may be passed along depends on the elasticities of supply and demand. Let's consider some examples.

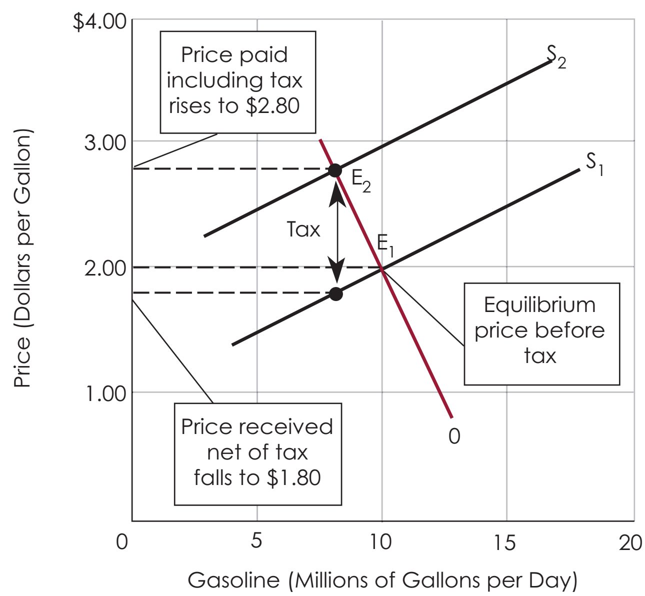
INCIDENCE OF A GASOLINE TAX First consider the familiar example of a gasoline tax. Specifically, suppose that the state of Virginia decides to impose a tax of

$1 per gallon on gasoline beginning from a situation in which there is no tax. The tax is assessed against sellers of gasoline, who add the tax into the price paid by consumers at the pump.

Figure 3.4 uses the supply-and-demand model to show the effects of the tax. Initially, the demand curve intersects supply curve S_1 at E_1, resulting in a price of $2 per gallon. The supply curve is elastic in the region of the initial equilibrium. The elasticity of supply reflects the fact that we are dealing with the gasoline market in just one state; only a slight rise in the price in Virginia is needed to divert additional quantities of gasoline from elsewhere in the nation, because of the wide geographic reach of the wholesale gasoline market. The retail gasoline market is more local. If the price in Virginia rises, some consumers living near the border may cross a state line to fill up in Maryland or North Carolina, but most people will continue to fill up in Virginia. In the short run, they have only limited ways to save gas, such as cutting back on non-essential trips. As a result, demand for gasoline is less elastic than the supply in the region of the initial equilibrium.

The effect of the tax is to shift the supply curve to the left until each point on the new supply curve is exactly $1 higher than the point for the corresponding quantity

FIGURE 3.4 INCIDENCE OF A TAX ON GASOLINE



S_1 and D are the supply and demand curves before imposition of the tax. The initial equilibrium price is $2 per gallon. A tax of $1 per gallon shifts the supply curve to S_2. To induce sellers to supply the same quantity as before, the price would have to rise to $3. However, as the price rises, buyers reduce the quantity demanded, moving up and to the left along the demand curve. In the new equilibrium at E_2, the price rises only to $2.80. After the tax is paid, sellers receive only $1,80 per gallon. Thus, buyers bear $.80 of the tax on each gallon and sellers the remaining $.20. Buyers bear the larger share of the tax because demand, in this case, is less elastic than supply.

on the old supply curve. (We could instead say that the supply curve shifts *upward* by $1.) Because sellers must now turn over $1 to the state government for each gallon of gas sold, they would have to get $3 per gallon to be willing to sell the same quantity (10 million gallons per day) as initially. However, when sellers attempt to pass the tax on to motorists, motorists respond by reducing the amount of gas they buy. As the quantity sold falls, sellers move down and to the left along supply curve S_2 to a new equilibrium at E_2.

In the new equilibrium, the price is $2.80 per gallon—just $.80 higher than the original price. The new price includes the $1 tax, which sellers add to their net price of $1.80 per gallon—a net price that is $.20 less than before. The amount of the tax—$1 per gallon—is shown by the vertical gap between the supply and demand curves. The economic burden of the tax is divided between buyers and sellers, but in this case it falls more heavily on the buyers.

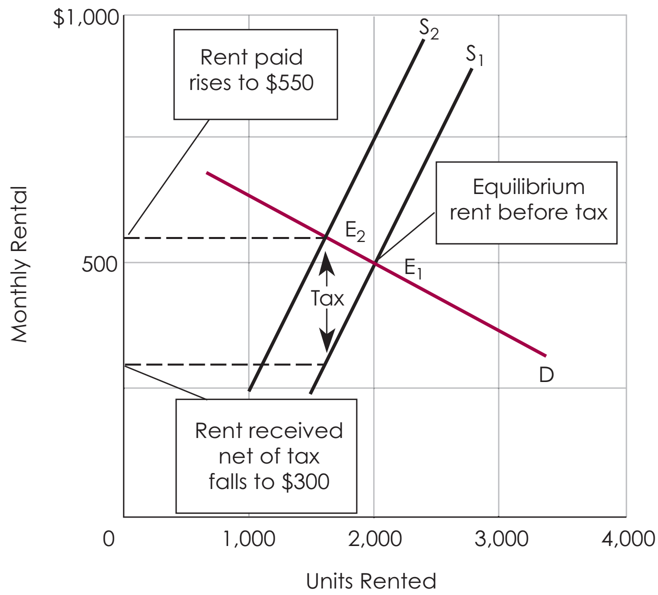
INCIDENCE OF A TAX ON APARTMENT RENTS In the preceding example, the incidence of the gasoline tax falls more heavily on buyers than on sellers because demand is less elastic than supply. If the elasticities are reversed, the results will also be reversed, as can be seen in the case of a tax on apartment rents.

In Figure 3.5, the market for rental apartments in Ogden, Utah (a small city) is initially in equilibrium at $500 per month. The supply of rental apartments is inelastic. An increase in rents will cause a few new apartments to be built, whereas a reduction will cause a few to be torn down, but in either case the response will be moderate. On the other hand, demand is fairly elastic, because potential renters consider houses or condominiums a fairly close substitute for rental apartments.

Given this situation, suppose that the local government decides to impose a tax of $250 per month on all apartments rented in Ogden. This tax, like the gasoline tax, is assessed against landlords, who include the tax payment in the monthly rental they charge to tenants. As in the previous example, the tax shifts the supply curve to the left until each point on the new supply curve lies above the corresponding point on the old supply curve by the amount of the tax. (Again, we could instead say the supply curve shifts upward by the amount of the tax.) After the shift, the market reaches a new equilibrium at E_2. There the rental price paid by tenants rises to only $550 per month, as indicated by the intersection of the new supply and demand curves. Landlords succeed in passing only $50 of the $250 monthly tax along to tenants. Their net rental income, after turning over the tax receipts to the town government, is now just $300, down from $500 before imposition of the tax. In this case, because supply is inelastic and demand is elastic, suppliers bear most of the incidence of the tax and buyers only a little.

INCIDENCE AND TAX REVENUE When the government considers imposing a tax on gasoline, cigarettes, apartments, or any other item, the price elasticity of demand and supply is important not only for how the burden is shared between buyers

FIGURE 3.5 INCIDENCE OF A TAX ON APARTMENT RENTS



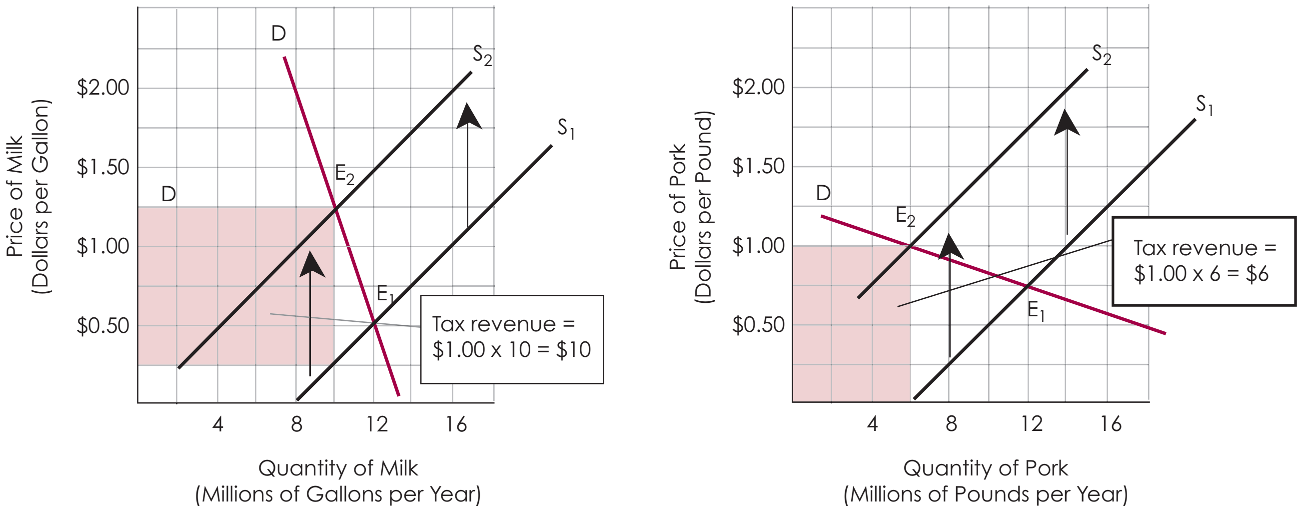
This figure shows the incidence of a tax imposed in a market in which supply is less elastic than demand. Initially, the equilibrium rent is $500 per month. A $250-per-month tax on apartment rents shifts the supply curve to S_2. The new equilibrium is at E_2. Landlords end up absorbing all but $50 of the tax. If they tried to pass more of the tax on to renters, more renters would switch to owner-occupied housing, and the vacancy rate on rental apartments would rise.

and sellers, but also for how much tax revenue the government collects. When buyers or sellers are more responsive to changes in price (when demand or supply is more elastic), a tax will generate less revenue for the government.

Figure 3.6 compares the markets for two items: milk and pork. The elasticities of supply are similar, but the price elasticities of demand differ. Pork has many obvious substitutes—beef, chicken, turkey, and other meats. Milk has few substitutes, so its demand is more inelastic. The markets for milk and pork are shown in Figure 3.6. The equilibrium price of milk is $0.50 per gallon and 12 million gallons are sold each year at this price. The milk market equilibrium is point E_1 on the left panel of Figure 3.6. The equilibrium (shown by the point E_1 on the right panel of Figure 3.6) is $0.75 per pound and 12 million pounds are sold each year.

Suppose now that the government imposes a $1.00 tax on each product. In the milk market, where demand is inelastic, the tax leads to a small decrease in the quantity, from 12 to 10 million gallons. The government collects $1.00 on each gallon of milk sold, for tax revenue of $10 million on the 10 million gallons sold after the tax. In the market for pork, the tax leads to a larger reduction in the quantity people buy, from 12 to 6 million pounds. The government will collect a total of $6 million from

FIGURE 3.6



A tax imposed on a good that has an inelastic demand will generate more tax revenue than a tax on a good with elastic demand, assuming similar supply conditions. The diagrams above compare the effects of a $1.00 tax on the markets for milk (inelastic demand) and pork (elastic demand). In the market for milk, the tax reduces the equilibrium quantity by 2 million gallons, from point E_1 (12 million gallons) to E_2 (10 million gallons). Therefore, the government collects a total of $10 million from the milk tax. The same $1.00 tax on pork causes a large reduction in the quantity sold, from 12 million pounds (point E_1) to 6 million pounds (point E_2). This means the government will only collect $6 million, as only 6 million pounds of pork are sold at the new equilibrium.

the tax on pork, collecting $1.00 on each of the 6 million pounds sold. When comparing the two taxes, the government collects more revenue from the tax on milk. Today, governments rely for most of their revenue on broad-based taxes like income taxes, sales taxes, and value-added taxes. In past centuries, however, taxes on individual goods were more important than they are now. In those days, taxes on goods with highly inelastic demand—like salt, tobacco, and matches—were especially popular.

Elasticity and Prohibition

In the case of gasoline and apartment rents, a tax led to a reduction in the quantity consumed, which we characterized as an unintended consequence of the tax. In a few cases, the reduction in quantity consumed may be an *intended* consequence of the tax. Modern taxes on tobacco products are one example: because tobacco is regarded as harmful, a reduction in quantity consumed is seen as desirable. Taxes on environmentally harmful products, such as the chemicals responsible for ozone depletion, are another example.

Prohibition is a more extreme policy aimed at reducing the quantity of a product consumed. Alcoholic beverages were subject to prohibition in the United States during the 1920s, and drugs like marijuana, heroin, and cocaine are subject to prohibition today. Prohibition is a common method of environmental regulation as well. For example, use of the pesticide DDT and lead additives for gasoline are completely prohibited in the United States.

On the surface, a policy of prohibition may seem very different from a tax, since unlike a tax, prohibition raises no tax revenue for the government. However, if we use economic analysis to look below the surface, we see some similarities as well as differences between taxation and prohibition.

First, passage of a law prohibiting production and sale of a good does not make it impossible to supply the good, but simply more expensive. After the prohibition is in effect, the supplier must consider not only the direct costs of production, but the extra costs of covert transportation and distribution systems, the risk of fines or jail terms, the costs of hiring armed gangsters to protect illegal laboratories, and so on. From the law-breaking supplier's point of view, these costs can be seen as an implicit tax. If the price rises by enough to cover them, the good will still be supplied. Thus, the effect of prohibition of a good is to shift its supply curve to the left until each point on the new supply curve lies above the corresponding point on the old curve by a distance equal to the extra costs associated with evading the prohibition.

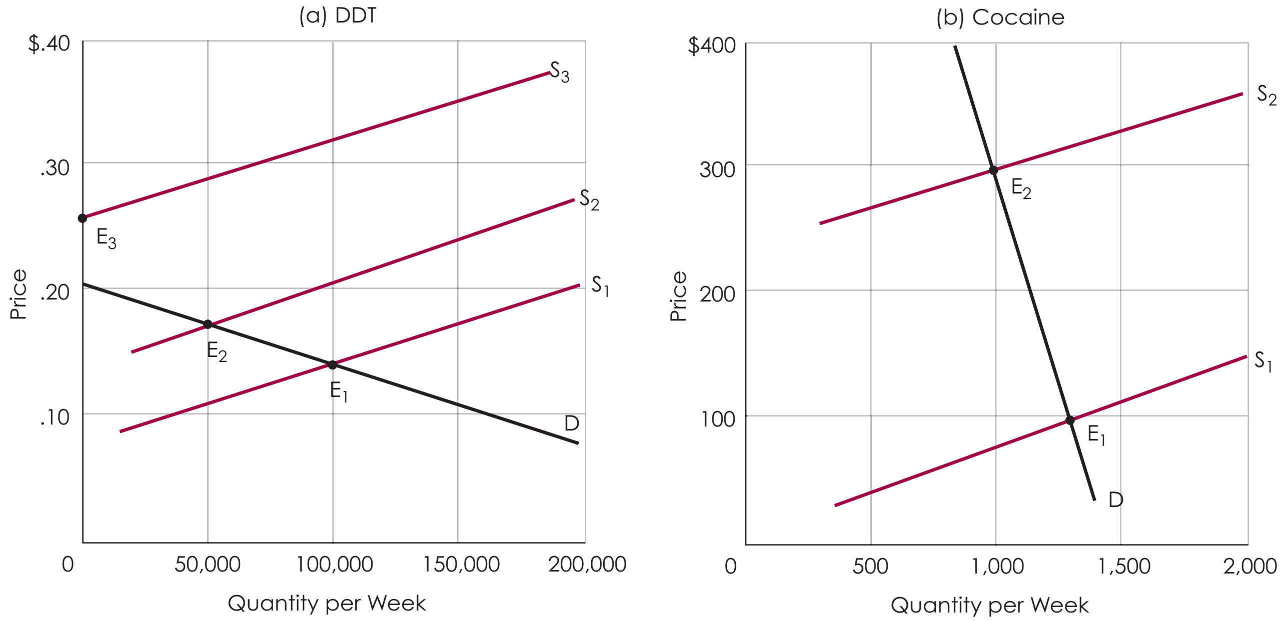
Second, the effects of the prohibition, like those of a tax, depend on the elasticities of demand and supply. This is illustrated in Figure 3.7, which compares the effects of prohibition on the U.S. markets for DDT and cocaine. The demand for DDT is shown as elastic because effective substitutes are available at a price only a little higher than the banned pesticide. The demand for cocaine is shown as inelastic, in part because once people become addicted, they will be very reluctant to curtail their use of the drug even if its price rises sharply.

In the case of elastic demand for DDT (Figure 3.7a), even a weakly enforced prohibition, which raises costs of illegal supply only a little, will sharply reduce the quantity sold. Such a weak prohibition, represented by a shift in the supply curve from S_1 to S_2, is already enough to reduce the total revenue (price times quantity sold) earned by producers from \$14,000 per week to \$8,500 per week. A more vigorously enforced prohibition, as represented by supply curve S_3, raises the cost of supply by enough to eliminate use of the product altogether.

In the case of cocaine, with its inelastic demand, even a strongly enforced prohibition has a small effect on quantity sold. This case is represented in Figure 3.7b by a shift in the supply curve to S_2. Because quantity demanded is not much affected by the price increase, total revenue from the sale of cocaine rises sharply, from \$130,000 per week at equilibrium E_1 to \$300,000 per week at equilibrium E_2. As long as demand is inelastic, increasing strictness of enforcement, which drives the supply curve still higher, will make the sales revenue of drug suppliers increase still further.

Elasticity of demand is important in understanding the intended and unintended consequences of prohibition. The intended consequence, of course, is to reduce or eliminate use of the product. As we see, the more elastic the demand for the product, the more successful is the policy of prohibition in achieving its intended effects. The unintended effects of prohibition are those associated with

FIGURE 3.7 ELASTICITY AND THE EFFECTS OF PROHIBITION



A law prohibiting production and sale of a good, like a tax on the good, shifts its supply curve to the left. The new supply curve will lie above the old supply curve at any given quantity by a distance equal to the cost of evading the prohibition. The effects on price, quantity, and revenue depend on the elasticity of demand. Part (a) uses DDT to illustrate prohibition of a good with elastic demand. A weakly enforced prohibition (S_2) raises the price, reduces the quantity, and reduces total revenue earned by producers from sale of the product. A strongly enforced prohibition reduces quantity and revenue to zero (S_3). Part (b) uses cocaine to illustrate prohibition of a good with inelastic demand. In this case, even strong efforts to enforce prohibition do not reduce quantity sold to zero. Because quantity sold increases by a smaller percentage than price increases, there is an increased total revenue and expenditure on the good.

the change in revenue that the policy produces. These are very different in the case of elastic and inelastic demand.

Where demand is elastic, there is a moderate loss of revenue to DDT producers and a small rise in the cost of growing crops as farmers switch to more expensive pesticides. Neither has major social consequences. The loss of revenue from producing DDT will be offset by increased revenue from production of substitutes, very likely by the same companies. And the increased cost of growing crops is offset by the benefits of a cleaner environment.

On the other hand, where demand is inelastic, the intended consequences are smaller and the unintended consequences greater. With inelastic demand, prohibition increases total expenditure on the banned product. The social consequences may be severe. First, users of cocaine must spend more to sustain their habit. At best this means impoverishing themselves and their families; at worst it means an increase in muggings and armed robberies by users desperate for cash. Second, the impact of the prohibition on suppliers must be considered as well. For suppliers, the increase in revenue does not just mean an increase in profit (although profits may increase), but also an increase in expenditures devoted to evading prohibition. In part, the result is simply wasteful, as when drug suppliers buy an airplane to make a single one-way flight rather than using normal transportation methods. Worse, another part of suppliers' increased expenditures take the form of hiring armies of thugs to battle the police and other suppliers, further raising the level of violence on city streets, or bribing government officials, thereby corrupting the quality of government.

The issue of drug prohibition, of course, involves many normative issues that reach far beyond the concept of elasticity. One such issue is whether people have a right to harm themselves through consumption of substances like tobacco, alcohol, or cocaine, or whether, instead, the government has a duty to act paternalistically to prevent such harm. Another concerns the relative emphasis that should be placed on prohibition versus treatment in allocating resources to reduce drug use. The analysis given here cannot answer such questions. However, it does suggest that the law of unintended consequences applies in the area of drug policy as elsewhere, and that elasticity of demand is important in determining the nature and severity of those consequences.

SUMMARY

1. **How can the responsiveness of quantity demanded to a price change be expressed in terms of elasticity?** *Elasticity* is the responsiveness of quantity demanded or supplied to changes in the price of a good (or changes in other factors), measured as a ratio of the percentage change in quantity to the percentage change in price (or other factor causing the change in quantity). The *price elasticity of demand* between two points on a demand curve is the percentage change in quantity demanded divided by the percentage change in the good's price.

2. **How is the elasticity of demand for a good related to the revenue earned by its seller?** If the demand for a good is elastic, a decrease in its price will increase total revenue. If it is inelastic, an increase in its price will increase total revenue. When the demand for a good is unit elastic, revenue will remain constant as the price varies.

3. **How can elasticity be applied to changes in market conditions other than price?** The concept of elasticity can be applied to many situations besides movements along demand curves. The *income elasticity of demand* for a good is the ratio of the percentage change in quantity demanded to a given percentage change in income. The *cross-elasticity of demand* between goods A and B is the ratio of the percentage change in the quantity of good A demanded to a given percentage change in the price of good B. The *price elasticity of supply* is the ratio of the percentage change in the quantity of a good supplied to a given change in its price.

4. **What determines the distribution of the economic burden of a tax?** The way in which the economic burden of a tax is distributed is known as the *incidence* of the tax. The incidence depends on the relative elasticities of supply and demand. If supply is relatively more elastic than demand, buyers will bear the larger share of the tax burden. If demand is relatively more elastic than supply, the larger share of the burden will fall on sellers. If the good is subject to prohibition rather than to a tax, elasticity of demand will determine how many resources are likely to be devoted to enforcement and evasion of the prohibition.

KEY TERMS

Elasticity
Price elasticity of demand
Revenue
Elastic demand
Inelastic demand
Unit elastic demand
Perfectly inelastic demand
Perfectly elastic demand
Income elasticity of demand
Cross-elasticity of demand
Price elasticity of supply
Tax incidence

PROBLEMS AND TOPICS FOR DISCUSSION

1. **Time horizon and elasticity.** Suppose a virus infects the California lettuce crop, cutting production by half. Consider three time horizons: (a) The "very short" run means a period that is too short to allow farmers to change the amount of lettuce that has been planted. No matter what happens to the price, the quantity supplied will be the amount already planted, less the amount destroyed by the virus. (b) The "intermediate" run means a period that is long enough to allow farmers to plant more fields in lettuce, but not long enough to permit them to develop new varieties of lettuce, introduce new methods of cultivation, or acquire new specialized equipment. (c) The "long" run means a period that is long enough to allow farmers to develop new varieties of virus-resistant lettuce and improve cultivation techniques. Discuss these three time horizons in terms of the price elasticity of supply. Sketch a figure showing supply curves for each of the time horizons.

2. **Calculating elasticity.** Draw a set of coordinate axes on a piece of graph paper. Label the horizontal axis from 0 to 50 units and the vertical axis from $0 to $20 per unit. Draw a demand curve that intersects the vertical axis at $10 and the horizontal axis at 40 units. Draw a supply curve that intersects the vertical axis at $4 and has a slope of 1. Make the following calculations for these curves, using the midpoint formula:

   a. What is the price elasticity of demand over the price range $5 to $7?

   b. What is the price elasticity of demand over the price range $1 to $3?

   c. What is the price elasticity of supply over the price range $10 to $15?

   d. What is the price elasticity of supply over the price range $15 to $17?

3. **Elasticity and revenue.** Look at the demand curve given in Figure 2.1 of the preceding chapter. Make a third column in the table that gives revenue for each price-quantity combination shown. Draw a set of axes on a piece of graph paper. Label the horizontal axis as in Figure 2.1, and label the vertical axis from 0 to $5 billion of revenue in increments of $1 billion. Graph the relationship between quantity and revenue using the column you added to the table. Discuss the

relationship of your revenue graph to the demand curve, keeping in mind what you know about elasticity and revenue and about variation in elasticity along the demand curve.

4. **Elasticity of demand and revenue.** Assume that you are an officer of your campus film club. You are at a meeting at which ticket prices are being discussed. One member says, "What I hate to see most of all is empty seats in the theater. We sell out every weekend showing, but there are always empty seats on Wednesdays. If we cut our Wednesday night prices by enough to fill up the theater, we'd bring in more money." Would this tactic really bring in more revenue? What would you need to know in order to be sure? Draw diagrams to illustrate some of the possibilities.

5. **Cross-elasticity of demand.** Between 1979 and 1981 the price of heating oil rose by 104 percent. Over the same period, use of fuel oil fell slightly while use of LP gas, another heating fuel, rose. Assuming that there was no change in the price of LP gas, what does this suggest about the cross-elasticity of demand for LP gas with respect to the price of fuel oil? Draw a pair of diagrams to illustrate these events. (Suggestion: Draw upward-sloping supply curves for both fuels. Then assume that the supply curve for heating oil shifts upward while the supply curve for LP gas stays the same.)

CASE FOR DISCUSSION

VP Asks Cigarette Firms for Sacrifice

Rendi A. Witular, *The Jakarta Post,* Jakarta, Indonesia, June 1, 2005

The lower profits cigarette-makers were likely to experience when the government raises the retail price on cigarettes should be viewed as a sacrifice to the state, [Indonesian] Vice President Jusuf Kalla said on Tuesday.

"The tobacco industry is one of the most profitable sectors in [Indonesian] business. Raising the (retail) rate won't affect tobacco firms much, since they will still be able to make a profit. Remember that cigarette prices here are still the lowest in the world," Kalla said.

By increasing the retail price of cigarettes the government planned to make more money on the excise duty it charged manufacturers, which was calculated on the final retail price.

The amount of the increase has not been finalized but last week the Minister of Finance Jusuf Anwar suggested it would be in the range of 15 to 20 percent. This extra revenue would help plug the state budget deficit that has increased in line with the rising costs of the government's fuel subsidy.

PT H. M. Sampoerna, the country's second-largest cigarette maker by sales, said that more than a 10 percent increase in the cigarette prices could hurt producers as it would affect sales.

Sampoerna is 98 percent-owned by U.S. cigarette giant Philip Morris International.

"Less than a 10 percent increase in the price is likely to be OK, but more (than that) could disturb sales," Sampoerna director Angky Camaro said after meeting Kalla earlier in the day.

Angky said the industry had not yet fully recovered from the aggressive excise rate hikes in 2002 and 2003, which had resulted in declines in the volumes of cigarette produced and lower profits across the board.

Last year, local cigarette company profits rose on increased consumption spurred on by higher general economic growth and the absence of any increases in excise duty.

The Indonesian Cigarette Producer Union (Gappri) estimates that some 141 million of the country's 220 million people are smokers.

Source: Rendi A. Witular, *The Jakarta Post,* Jakarta, Indonesia, June 1, 2005 (Downloaded June 5, 2005 from http://www.thejakartapost.com/yesterdaydetail.asp?field=20050601.L04).

QUESTIONS

1. On the basis of this article, do you think that price elasticity of demand for cigarettes in Indonesia is elastic, inelastic, unit elastic, perfectly elastic, or perfectly inelastic? Cite the specific passages supporting your conclusion, and note any apparent contradictions in the article.
2. According to the article, 64 percent of the people of Indonesia, where cigarette prices are among the lowest in the world, are smokers, compared to less than 25 percent in the United States, where prices are higher. What does this suggest about the price elasticity of demand for tobacco in the long run? Why might the long-run elasticity of demand for cigarettes be greater than the short-run elasticity?
3. According to Angky Camaro of Sampoerna, a tax increase that reduced quantity sold would hurt producers. Using a diagram similar to Figure 3.4, explain why this would be true even if the percentage decrease in quantity were less than the percentage increase in price.
4. According to the article, in 2004, cigarette sales increased as income increased, while taxes were unchanged. What does this tell you about the income elasticity of demand?

END NOTES

1. As we have said, the midpoint formula (also sometimes called *arc-elasticity*) is not the only one for calculating elasticity. A drawback of this formula is that it can give misleading elasticity values if applied over too wide a variation in price or quantity. Because of this limitation, it is often suggested that the midpoint formula be used only over fairly small ranges of variation in price or quantity. Following this reasoning to its logical conclusion, there is an alternative formula for calculating elasticity for a single point on the demand curve. For a linear demand curve having the formula $q = a - bp$ (with q representing quantity demanded, p the price, and a and b being constants), the *point formula* for elasticity of demand (stated, as elsewhere, as a positive number) is

$$\text{Elasticity} = bp/(a - bp).$$

2. Jonq-Ying Lee, Mark G. Brown, and Brooke Schwartz, “The Demand for National Brand and Private Label Frozen Concentrated Orange Juice: A Switching Regression Analysis,” *Western Journal of Agricultural Economics* (July 1986): 1–7.