AFTER READING THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. **Discuss price elasticity of demand and how it can be applied.**
2. **Explain the usefulness of the total revenue test for price elasticity of demand.**
3. **Describe price elasticity of supply and how it can be applied.**
4. **Apply cross elasticity of demand and income elasticity of demand.**

4

Elasticity

In this chapter we extend Chapter 3's discussion of demand and supply by explaining *elasticity,* an extremely important concept that helps us answer such questions as: Why do buyers of some products (for example, ocean cruises) respond to price increases by substantially reducing their purchases while buyers of other products (say, gasoline) respond by only slightly cutting back their purchases? Why do higher market prices for some products (for example, chicken) cause producers to greatly increase their output while price rises for other products (say, gold) cause only limited increases in output? Why does the demand for some products (for example, books) rise a great deal when household income increases while the demand for other products (say, milk) rises just a little?

Elasticity extends our understanding of markets by letting us know the degree to which changes in prices and incomes affect supply and demand. Sometimes the responses are substantial, other times minimal or even nonexistent. But by knowing what to expect, businesses and the government can do a better job in deciding what to produce, how much to charge, and, surprisingly, what items to tax.

Price Elasticity of Demand

The law of demand tells us that, other things equal, consumers will buy more of a product when its price declines and less when its price increases. But how much more or less will they buy? The amount varies from product to product and over different price ranges for the same product. It also may vary over time. And such variations matter. For example, a firm contemplating a price hike will want to know how consumers will respond. If they remain highly loyal and continue to buy, the firm's revenue will rise. But if consumers defect en masse to other sellers or other products, the firm's revenue will tumble.

The responsiveness (or sensitivity) of consumers to a price change is measured by a product's **price elasticity of demand.** For some products—for example, restaurant meals—consumers are highly responsive to price changes. Modest price changes cause very large changes in the quantity purchased. Economists say that the demand for such products is *relatively elastic* or simply *elastic.*

> **ORIGIN OF THE IDEA**
> O 4.1
> Price elasticity of demand

For other products—for example, toothpaste—consumers pay much less attention to price changes. Substantial price changes cause only small changes in the amount purchased. The demand for such products is *relatively inelastic* or simply *inelastic.*

The Price-Elasticity Coefficient and Formula

Economists measure the degree to which demand is price elastic or inelastic with the coefficient E_d, defined as

$$E_d = \frac{\text{percentage change in quantity demanded of product X}}{\text{percentage change in price of product X}}$$

The percentage changes in the equation are calculated by dividing the *change* in quantity demanded by the original quantity demanded and by dividing the *change* in price by the original price. So we can restate the formula as

$$E_d = \frac{\text{change in quantity demanded of X}}{\text{original quantity demanded of X}} \div \frac{\text{change in price of X}}{\text{original price of X}}$$

Using Averages Unfortunately, an annoying problem arises in computing the price-elasticity coefficient. A price change from, say, \$4 to \$5 along a demand curve is a 25 percent (= \$1/\$4) increase, but the opposite price change from \$5 to \$4 along the same curve is a 20 percent (= \$1/\$5) decrease. Which percentage change in price should we use in the denominator to compute the price-elasticity coefficient? And when quantity changes, for example, from 10 to 20, it is a 100 percent (=10/10) increase. But when quantity falls from 20 to 10 along the identical demand curve, it is a 50 percent (=10/20) decrease. Should we use 100 percent or 50 percent in the numerator of the elasticity formula? Elasticity should be the same whether price rises or falls!

The simplest solution to the problem is to use the **midpoint formula** for calculating elasticity. This formula simply averages the two prices and the two quantities as the reference points for computing the percentages. That is,

$$E_d = \frac{\text{change in quantity}}{\text{sum of quantities}/2} \div \frac{\text{change in price}}{\text{sum of prices}/2}$$

For the same \$5–\$4 price range, the price reference is \$4.50 [= (\$5 + \$4)/2], and for the same 10–20 quantity range, the quantity reference is 15 units [= (10 + 20)/2]. The percentage change in price is now \$1/\$4.50, or about 22 percent, and the percentage change in quantity is $\frac{10}{15}$ or about 67 percent. So E_d is about 3. This solution eliminates the "up versus down" problem. All the price-elasticity coefficients that follow are calculated using this midpoint formula.

> **WORKED PROBLEMS**
> W 4.1
> Elasticity of demand

Using Percentages Why use percentages rather than absolute amounts in measuring consumer responsiveness? There are two reasons.

First, if we use absolute changes, the choice of units will arbitrarily affect our impression of buyer responsiveness. To illustrate: If the price of a bag of popcorn at the local softball game is reduced from \$3 to \$2 and consumers increase their purchases from 60 to 100 bags, it will seem that consumers are quite sensitive to price changes and therefore that demand is elastic. After all, a price change of 1 unit has caused a change in the amount demanded of 40 units. But by changing the monetary unit from dollars to pennies (why not?), we find that a price change of 100 units (pennies) causes a quantity change of 40 units. This may falsely lead us to believe that demand is inelastic. We avoid this problem by using percentage changes. This particular price decline is the same whether we measure it in dollars or pennies.

Second, by using percentages, we can correctly compare consumer responsiveness to changes in the prices of different products. It makes little sense to compare the effects on quantity demanded of (1) a \$1 increase in the price of a \$10,000 used car with (2) a \$1 increase in the price of a \$1 soft drink. Here the price of the used car has increased by .01 percent while the price of the soft drink is up by 100 percent. We can more sensibly compare the consumer responsiveness to price increases by using some common percentage increase in price for both.

Elimination of Minus Sign We know from the downsloping demand curve that price and quantity demanded are inversely related. Thus, the price-elasticity coefficient of demand E_d will always be a negative number. As an example, if price declines, then quantity demanded will increase. This means that the numerator in our formula will be positive and the denominator negative, yielding a negative E_d. For an increase in price, the numerator will be negative but the denominator positive, again yielding a negative E_d.

Economists usually ignore the minus sign and simply present the absolute value of the elasticity coefficient to avoid an ambiguity that might otherwise arise. It can be confusing to say that an E_d of -4 is greater than one of -2. This possible confusion is avoided when we say an E_d of 4 reveals greater elasticity than one of 2. So, in what follows, we ignore the minus sign in the coefficient of price elasticity of demand and show only the absolute value. Incidentally, the ambiguity does not arise with supply because price and quantity supplied are positively related. All elasticity of supply coefficients therefore are positive numbers.

Interpretations of E_d

We can interpret the coefficient of price elasticity of demand as follows.

Elastic Demand Demand is **elastic** if a specific percentage change in price results in a larger percentage change in quantity demanded. In such cases, E_d will be greater than 1. Example: Suppose that a 2 percent decline in the price of cut flowers results in a 4 percent increase in quantity demanded. Then demand for cut flowers is elastic and

$$E_d = \frac{.04}{.02} = 2$$

Inelastic Demand If a specific percentage change in price produces a smaller percentage change in quantity demanded, demand is **inelastic.** In such cases, E_d will be less than 1. Example: Suppose that a 2 percent decline in the price of coffee leads to only a 1 percent increase in quantity demanded. Then demand is inelastic and

$$E_d = \frac{.01}{.02} = .5$$

Unit Elasticity The case separating elastic and inelastic demands occurs where a percentage change in price and the resulting percentage change in quantity demanded are the same. Example: Suppose that a 2 percent drop in the price of chocolate causes a 2 percent increase in quantity demanded. This special case is termed **unit elasticity** because E_d is exactly 1, or unity. In this example,

$$E_d = \frac{.02}{.02} = 1$$

Extreme Cases When we say demand is "inelastic," we do not mean that consumers are completely unresponsive to a price change. In that extreme situation, where a price change results in no change whatsoever in the quantity demanded, economists say that demand is **perfectly inelastic.** The price-elasticity coefficient is zero because there is no response to a change in price. Approximate examples include an acute diabetic's demand for insulin or an addict's demand for heroin. A line parallel to the vertical axis, such as D_1 in Figure 4.1a, shows perfectly inelastic demand graphically.

Conversely, when we say demand is "elastic," we do not mean that consumers are completely responsive to a price change. In that extreme situation, where a small price reduction causes buyers to increase their purchases from zero to all they can obtain, the elasticity coefficient is infinite ($= \infty$) and economists say demand is **perfectly elastic.** A line parallel to the horizontal axis, such as D_2 in Figure 4.1b, shows perfectly elastic demand. You will see in Chapter 8 that such a demand applies to a firm—say, a mining firm—that is selling its output in a purely competitive market.

The Total-Revenue Test

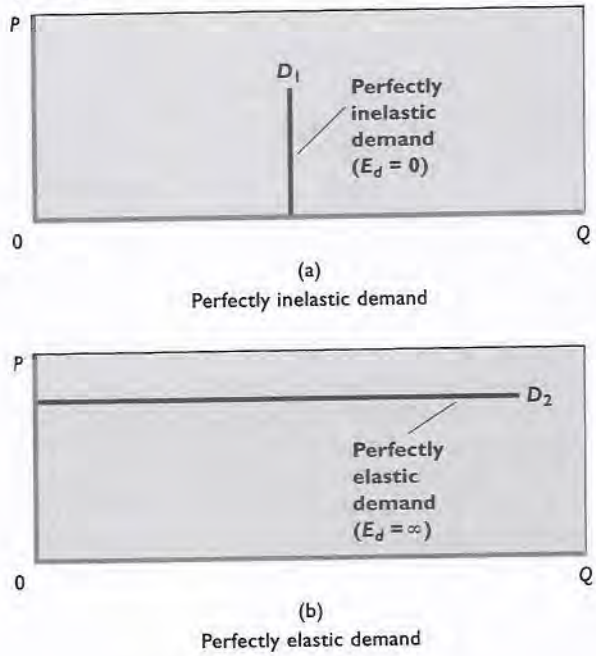
The importance of elasticity for firms relates to the effect of price changes on total revenue and thus on profits (= total revenue minus total costs).

Total revenue (TR) is the total amount the seller receives from the sale of a product in a particular time period; it is calculated by multiplying the product price (P) by the quantity sold (Q). In equation form:

$$\text{TR} = P \times Q$$

Graphically, total revenue is represented by the $P \times Q$ rectangle lying below a point on a demand curve. At point

FIGURE 4.1 Perfectly inelastic and elastic demands. Demand curve D_1 in (a) represents perfectly inelastic demand ($E_d = 0$). A price increase will result in no change in quantity demanded. Demand curve D_2 in (b) represents perfectly elastic demand. A price increase will cause quantity demanded to decline from an infinite amount to zero ($E_d = \infty$).



CONSIDER THIS . . .

A Bit of a Stretch

The following analogy might help you remember the distinction between "elastic" and "inelastic." Imagine two objects—one an Ace elastic bandage used to wrap injured joints and the other a relatively firm rubber tie-down (rubber strap) used for securing items for transport. The Ace bandage stretches a great deal when pulled with a particular force; the rubber tie-down stretches some, but not a lot.

Similar differences occur for the quantity demanded of various products when their prices change. For some products, a price change causes a substantial "stretch" of quantity demanded. When this stretch in percentage terms exceeds the percentage change in price, demand is elastic. For other products, quantity demanded stretches very little in response to the price change. When this stretch in percentage terms is less than the percentage change in price, demand is inelastic.

In summary:

- Elastic demand displays considerable "quantity stretch" (as with the Ace bandage).
- Inelastic demand displays relatively little "quantity stretch" (as with the rubber tie-down).

And through extension:

- Perfectly elastic demand has infinite quantity stretch.
- Perfectly inelastic demand has zero quantity stretch.

a in Figure 4.2a, for example, price is \$2 and quantity demanded is 10 units. So total revenue is \$20 (= \$2 × 10), shown by the rectangle composed of the yellow and green areas under the demand curve. We know from basic geometry that the area of a rectangle is found by multiplying one side by the other. Here, one side is "price" (\$2) and the other is "quantity demanded" (10 units).

Total revenue and the price elasticity of demand are related. In fact, the easiest way to infer whether demand is elastic or inelastic is to employ the **total-revenue test.** Here is the test: Note what happens to total revenue when price changes. If total revenue changes in the opposite direction from price, demand is elastic. If total revenue changes in the same direction as price, demand is inelastic. If total revenue does not change when price changes, demand is unit-elastic.

Elastic Demand If demand is elastic, a decrease in price will increase total revenue. Even though a lesser price is received per unit, enough additional units are sold to more than make up for the lower price. For an example, look at demand curve D_1 in Figure 4.2a. We have already established that at point *a*, total revenue is \$20 (= \$2 × 10), shown as the yellow plus green area. If the price declines from \$2 to \$1 (point *b*), the quantity demanded becomes 40 units and total revenue is \$40 (= \$1 × 40). As a result of the price decline, total revenue has increased from \$20 to \$40. Total revenue has increased in this case because the \$1 decline in price applies to 10 units, with a consequent revenue loss of \$10 (the yellow area). But 30 more units are sold at \$1 each, resulting in a revenue gain of \$30 (the blue area). Visually, the gain of the blue area clearly exceeds the loss of the yellow area. As indicated, the overall result is a net increase in total revenue of \$20 (= \$30 − \$10).

The analysis is reversible: If demand is elastic, a price increase will reduce total revenue. The revenue gained on the higher-priced units will be more than offset by the

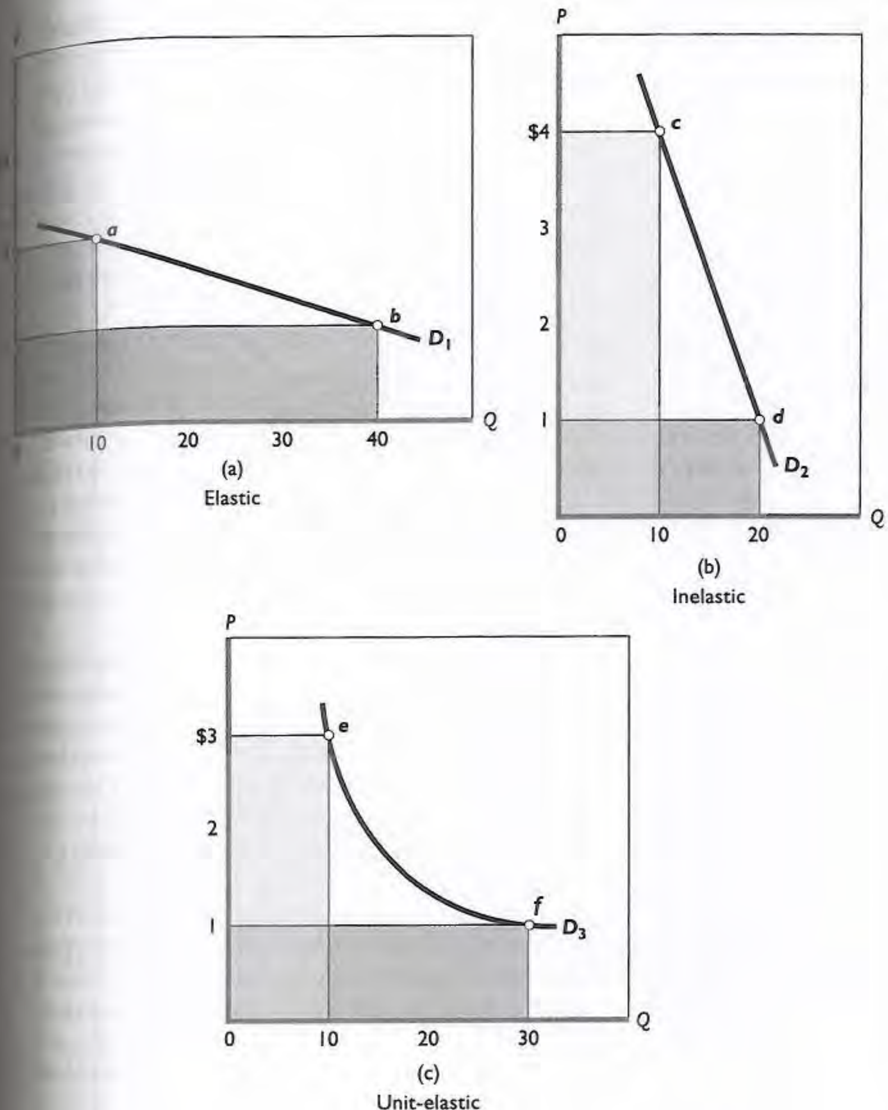


FIGURE 4.2 The total-revenue test for price elasticity. (a) Price declines from $2 to $1, and total revenue increases from $20 to $40. So demand is elastic. The gain in revenue (blue area) exceeds the loss of revenue (yellow area). (b) Price declines from $4 to $1, and total revenue falls from $40 to $20. So, demand is inelastic. The gain in revenue (blue area) is less than the loss of revenue (yellow area). (c) Price declines from $3 to $1, and total revenue does not change. Demand is unit-elastic. The gain in revenue (blue area) equals the loss of revenue (yellow area).

revenue lost from the lower quantity sold. Bottom line: Other things equal, when price and total revenue move in opposite directions, demand is elastic. E_d is greater than 1, meaning the percentage change in quantity demanded is greater than the percentage change in price.

Inelastic Demand If demand is inelastic, a price decrease will reduce total revenue. The increase in sales will not fully offset the decline in revenue per unit, and total revenue will decline. To see this, look at demand curve D_2 in Figure 4.2b. At point *c* on the curve, price is $4 and quantity demanded is 10. Thus total revenue is $40, shown by the combined yellow and green rectangle. If the price drops to $1 (point *d*), total revenue declines to $20, which obviously is less than $40. Total revenue has declined because the loss of revenue (the yellow area) from the lower unit price is larger than the gain in revenue (the blue area) from the accompanying increase in sales. Price has fallen, and total revenue has also declined.

Our analysis is again reversible: If demand is inelastic, a price increase will increase total revenue. So, other things equal, when price and total revenue move in the same direction, demand is inelastic. E_d is less than 1, meaning the percentage change in quantity demanded is less than the percentage change in price.

WORKED PROBLEMS

W 4.2

Total-revenue test

Unit Elasticity In the special case of unit elasticity, an increase or a decrease in price leaves total revenue unchanged. The loss in revenue from a lower unit price is exactly offset by the gain in revenue from the accompanying increase in sales. Conversely, the gain in revenue from a higher unit price is exactly offset by the revenue loss associated with the accompanying decline in the amount demanded.

In Figure 4.2c (demand curve D_3) we find that at the price of \$3, 10 units will be sold, yielding total revenue of \$30. At the lower \$1 price, a total of 30 units will be sold, again resulting in \$30 of total revenue. The \$2 price reduction causes the loss of revenue shown by the yellow area, but this is exactly offset by the revenue gain shown by the blue area. Total revenue does not change. In fact, that would be true for all price changes along this particular curve.

Other things equal, when price changes and total revenue remains constant, demand is unit-elastic (or unitary). E_d is 1, meaning the percentage change in quantity equals the percentage change in price.

Price Elasticity along a Linear Demand Curve

Now a major confession! Although the demand curves depicted in Figure 4.2 nicely illustrate the total-revenue test for elasticity, two of the graphs involve specific movements along linear (straight-line) demand curves. That presents no problem for explaining the total-revenue test. However, you need to know that elasticity typically varies over different price ranges of the same demand curve. (The exception is the curve in Figure 4.2c. Elasticity is 1 along the entire curve.)

Table 4.1 and Figure 4.3 demonstrate that elasticity typically varies over different price ranges of the same demand schedule or curve. Plotting the hypothetical data for movie tickets shown in columns 1 and 2 of Table 4.1 yields demand curve *D* in Figure 4.3. Observe that the demai curve is linear. But we see from column 3 of the table th the price elasticity coefficient for this demand curve d clines as we move from higher to lower prices. For ; downsloping straight-line and most other demand curv demand is more price-elastic toward the upper left (hei the \$5–\$8 price range of *D*) than toward the lower rig (here, the \$4–\$1 price range of *D*).

This is the consequence of the arithmetic properti of the elasticity measure. Specifically, in the upper-le segment of the demand curve, the percentage change quantity is large becau the original referen quantity is small. Sim larly, the percenta change in price is sm in that segment because the original reference price large. The relatively large percentage change in quanti divided by the relatively small change in price yields large E_d—an elastic demand.

INTERACTIVE GRAPHS
G 4.1
Elasticity and revenue

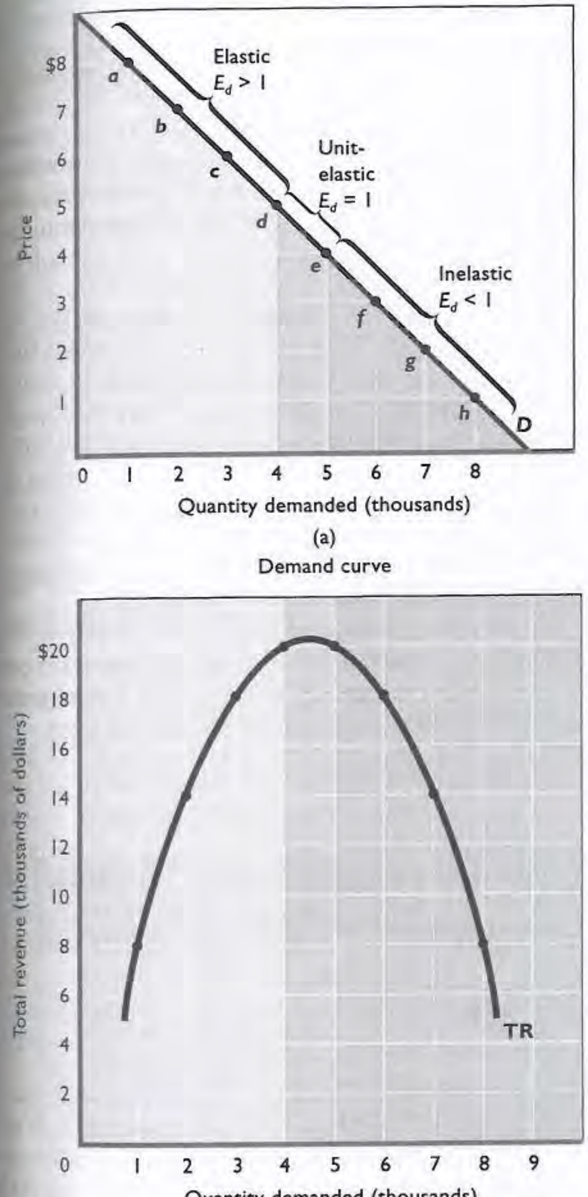
The reverse holds true for the lower-right segment the demand curve. Here the percentage change in qua tity is small because the original reference quantity large; similarly, the percentage change in price is large b cause the original reference price is small. The relative small percentage change in quantity divided by the rel tively large percentage change in price results in a sm E_d—an inelastic demand.

The demand curve in Figure 4.3a also illustrates th the slope of a demand curve—its flatness or steepness— not a sound basis for judging elasticity. The catch is th the slope of the curve is computed from *absolute* changes price and quantity, while elasticity involves *relative* or *pe centage* changes in price and quantity. The demand cur

TABLE 4.1 Price Elasticity of Demand for Movie Tickets as Measured by the Elasticity Coefficient and the Total-Revenue Test

(1) Total Quantity of Tickets Demanded per Week, Thousands	(2) Price per Ticket	(3) Elasticity Coefficient (E_d)	(4) Total Revenue, (1) × (2)	(5) Total-Revenue Test
1	\$8		\$ 8000	
		5.00		Elastic
2	7		14,000	
		2.60		Elastic
3	6		18,000	
		1.57		Elastic
4	5		20,000	
		1.00		Unit-elastic
5	4		20,000	
		0.64		Inelastic
6	3		18,000	
		0.38		Inelastic
7	2		14,000	
		0.20		Inelastic
8	1		8000	

FIGURE 4.3 The relation between price elasticity of demand for movie tickets and total revenue. Demand curve *D* in (a) is based on Table 4.1 and is marked to show that the hypothetical weekly demand for movie tickets is elastic at higher price ranges and inelastic at lower price ranges. The total-revenue curve TR in (b) is derived from demand curve *D*. When price falls and TR increases, demand is elastic; when price falls and TR is unchanged, demand is unit-elastic; and when price falls and TR declines, demand is inelastic.



In Figure 4.3a is linear, which by definition means that the slope is constant throughout. But we have demonstrated that such a curve is elastic in its high-price ($8–$5) range and inelastic in its low-price ($4–$1) range.

Price Elasticity and the Total-Revenue Curve

In Figure 4.3b we plot the total revenue per week to the theater owner that corresponds to each price-quantity combination indicated along demand curve *D* in Figure 4.3a. The price–quantity-demanded combination represented by point *a* on the demand curve yields total revenue of $8000 (= $8×1000 tickets). In Figure 4.3b, we plot this $8000 amount vertically at 1 unit (1000 tickets) demanded. Similarly, the price–quantity-demanded combination represented by point *b* in the upper panel yields total revenue of $14,000 (= $7×2000 tickets). This amount is graphed vertically at 2 units (2000 tickets) demanded in the lower panel. The ultimate result of such graphing is total-revenue curve TR, which first slopes upward, then reaches a maximum, and finally turns downward.

Comparison of curves *D* and TR sharply focuses the relationship between elasticity and total revenue. Lowering the ticket price in the elastic range of demand—for example, from $8 to $5—increases total revenue. Conversely, increasing the ticket price in that range reduces total revenue. In both cases, price and total revenue change in opposite directions, confirming that demand is elastic.

The $5–$4 price range of demand curve *D* reflects unit elasticity. When price either decreases from $5 to $4 or increases from $4 to $5, total revenue remains $20,000. In both cases, price has changed and total revenue has remained constant, confirming that demand is unit-elastic when we consider these particular price changes.

In the inelastic range of demand curve *D*, lowering the price—for example, from $4 to $1—decreases total revenue, as shown in Figure 4.3b. Raising the price boosts total revenue. In both cases, price and total revenue move in the same direction, confirming that demand is inelastic.

Table 4.2 summarizes the characteristics of price elasticity of demand. You should review it carefully.

Determinants of Price Elasticity of Demand

We cannot say just what will determine the price elasticity of demand in each individual situation. However, the following generalizations are often helpful.

Substitutability Generally, the larger the number of substitute goods that are available, the greater the price elasticity of demand. Various brands of candy bars are generally substitutable for one another, making the demand for one brand of candy bar, say Snickers, highly elastic. Toward the other extreme, the demand for tooth repair (or

TABLE 4.2 Price Elasticity of Demand: A Summary

Absolute Value of Elasticity Coefficient	Demand Is:	Description	Impact on Total Revenue of a: Price Increase	Price Decrease
Greater than 1 ($E_d > 1$)	Elastic or relatively elastic	Quantity demanded changes by a larger percentage than does price	Total revenue decreases	Total revenue increases
Equal to 1 ($E_d = 1$)	Unit- or unitary elastic	Quantity demanded changes by the same percentage as does price	Total revenue is unchanged	Total revenue is unchanged
Less than 1 ($E_d < 1$)	Inelastic or relatively inelastic	Quantity demanded changes by a smaller percentage than does price	Total revenue increases	Total revenue decreases

tooth pulling) is quite inelastic because there simply are no close substitutes when those procedures are required.

The elasticity of demand for a product depends on how narrowly the product is defined. Demand for Reebok sneakers is more elastic than is the overall demand for shoes. Many other brands are readily substitutable for Reebok sneakers, but there are few, if any, good substitutes for shoes.

Proportion of Income Other things equal, the higher the price of a good relative to consumers' incomes, the greater the price elasticity of demand. A 10 percent increase in the price of low-priced pencils or chewing gum amounts to a few more pennies relative to a consumer's income, and quantity demanded will probably decline only slightly. Thus, price elasticity for such low-priced items tends to be low. But a 10 percent increase in the price of relatively high-priced automobiles or housing means additional expenditures of perhaps $3000 or $20,000, respectively. These price increases are significant fractions of the annual incomes and budgets of most families, and quantities demanded will likely diminish significantly. The price elasticities for such items tend to be high.

Luxuries versus Necessities In general, the more that a good is considered to be a "luxury" rather than a "necessity," the greater is the price elasticity of demand. Electricity is generally regarded as a necessity; it is difficult to get along without it. A price increase will not significantly reduce the amount of lighting and power used in a household. (Note the very low price-elasticity coefficient of this good in Table 4.3.) An extreme case: A person does not decline an operation for acute appendicitis because the physician's fee has just gone up.

On the other hand, vacation travel and jewelry are luxuries, which, by definition, can easily be forgone. If the prices of vacation travel and jewelry rise, a consumer need not buy them and will suffer no great hardship without them.

TABLE 4.3 Selected Price Elasticities of Demand

Product or Service	Coefficient of Price Elasticity of Demand (E_d)	Product or Service	Coefficient of Price Elasticity of Demand (E_d)
Newspapers	.10	Milk	.63
Electricity (household)	.13	Household appliances	.63
Bread	.15	Liquor	.70
Major League Baseball tickets	.23	Movies	.87
Telephone service	.26	Beer	.90
Cigarettes	.25	Shoes	.91
Sugar	.30	Motor vehicles	1.14
Medical care	.31	Beef	1.27
Eggs	.32	China, glassware, tableware	1.54
Legal services	.37	Residential land	1.60
Automobile repair	.40	Restaurant meals	2.27
Clothing	.49	Lamb and mutton	2.65
Gasoline	.60	Fresh peas	2.83

Source: Compiled from numerous studies and sources reporting price elasticity of demand.