What you will learn in this Module:

- The difference between elastic and inelastic demand
- The relationship between elasticity and total revenue
- Changes in the price elasticity of demand along a demand curve
- The factors that determine price elasticity of demand

Module 11 Interpreting Price Elasticity of Demand

Interpreting the Price Elasticity of Demand

Med-Stat and other pharmaceutical distributors believed they could sharply drive up flu vaccine prices in the face of a shortage because the price elasticity of vaccine demand was low. But what does that mean? How low does a price elasticity have to be for us to classify it as low? How high does it have to be for us to consider it high? And what determines whether the price elasticity of demand is high or low, anyway? To answer these questions, we need to look more deeply at the price elasticity of demand.

How Elastic Is Elastic?

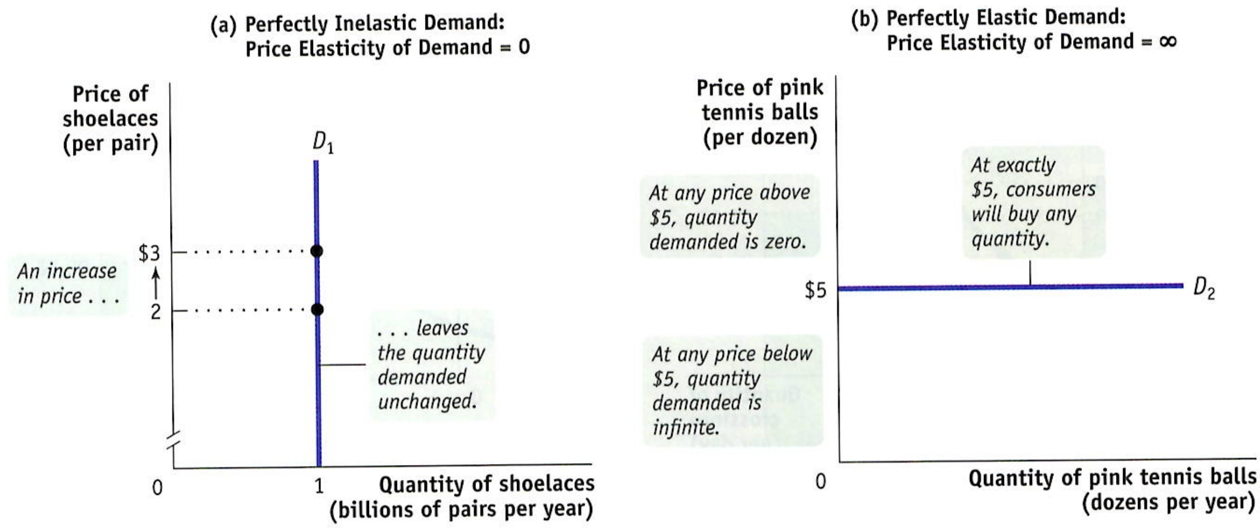
As a first step toward classifying price elasticities of demand, let's look at the extreme cases.

First, consider the demand for a good when people pay no attention to the price of, say, shoelaces. Suppose that consumers would buy 1 billion pairs of shoelaces per year regardless of the price. If that were true, the demand curve for shoelaces would look like the curve shown in panel (a) of Figure 11.1: it would be a vertical line at 1 billion pairs of shoelaces. Since the percent change in the quantity demanded is zero for *any* change in the price, the price elasticity of demand in this case is zero. The case of a zero price elasticity of demand is known as **perfectly inelastic** demand.

The opposite extreme occurs when even a tiny rise in the price will cause the quantity demanded to drop to zero or even a tiny fall in the price will cause the quantity demanded to get extremely large. Panel (b) of Figure 11.1 shows the case of pink tennis balls; we suppose that tennis players really don't care what color their balls are and that other colors, such as neon green and vivid yellow, are available at $5 per dozen balls. In this case, consumers will buy no pink balls if they cost more than $5 per dozen but will buy only pink balls if they cost less than $5. The demand curve will therefore be a horizontal line at a price of $5 per dozen balls. As you move back and forth along this line, there is a change in the quantity demanded but no change in the price. When you divide a number by zero, you get infinity, denoted by the symbol ∞.

Demand is **perfectly inelastic** when the quantity demanded does not respond at all to changes in the price. When demand is perfectly inelastic, the demand curve is a vertical line.

figure 11.1 Two Extreme Cases of Price Elasticity of Demand



Panel (a) shows a perfectly inelastic demand curve, which is a vertical line. The quantity of shoelaces demanded is always 1 billion pairs, regardless of price. As a result, the price elasticity of demand is zero—the quantity demanded is unaffected by the price. Panel (b) shows a perfectly elastic demand curve, which is a horizontal line. At a price of $5, consumers will buy any quantity of pink tennis balls, but will buy none at a price above $5. If the price falls below $5, they will buy an extremely large number of pink tennis balls and none of any other color.

So a horizontal demand curve implies an infinite price elasticity of demand. When the price elasticity of demand is infinite, economists say that demand is **perfectly elastic.**

The price elasticity of demand for the vast majority of goods is somewhere between these two extreme cases. Economists use one main criterion for classifying these intermediate cases: they ask whether the price elasticity of demand is greater or less than 1. When the price elasticity of demand is greater than 1, economists say that demand is **elastic.** When the price elasticity of demand is less than 1, they say that demand is **inelastic.** The borderline case is **unit-elastic** demand, where the price elasticity of demand is—surprise—exactly 1.

Demand is **perfectly elastic** when any price increase will cause the quantity demanded to drop to zero. When demand is perfectly elastic, the demand curve is a horizontal line.

Demand is **elastic** if the price elasticity of demand is greater than 1, **inelastic** if the price elasticity of demand is less than 1, and **unit-elastic** if the price elasticity of demand is exactly 1.

To see why a price elasticity of demand equal to 1 is a useful dividing line, let's consider a hypothetical example: a toll bridge operated by the state highway department. Other things equal, the number of drivers who use the bridge depends on the toll, the price the highway department charges for crossing the bridge: the higher the toll, the fewer the drivers who use the bridge.

Figure 11.2 on the next page shows three hypothetical demand curves—one in which demand is unit-elastic, one in which it is inelastic, and one in which it is elastic. In each case, point *A* shows the quantity demanded if the toll is $0.90 and point *B* shows the quantity demanded if the toll is $1.10. An increase in the toll from $0.90 to $1.10 is an increase of 20% if we use the midpoint method to calculate percent changes.

Panel (a) shows what happens when the toll is raised from $0.90 to $1.10 and the demand curve is unit-elastic. Here the 20% price rise leads to a fall in the quantity of cars using the bridge each day from 1,100 to 900, which is a 20% decline (again using the midpoint method). So the price elasticity of demand is 20%/20% = 1.

Panel (b) shows a case of inelastic demand when the toll is raised from $0.90 to $1.10. The same 20% price rise reduces the quantity demanded from 1,050 to 950. That's only a 10% decline, so in this case the price elasticity of demand is 10%/20% = 0.5.

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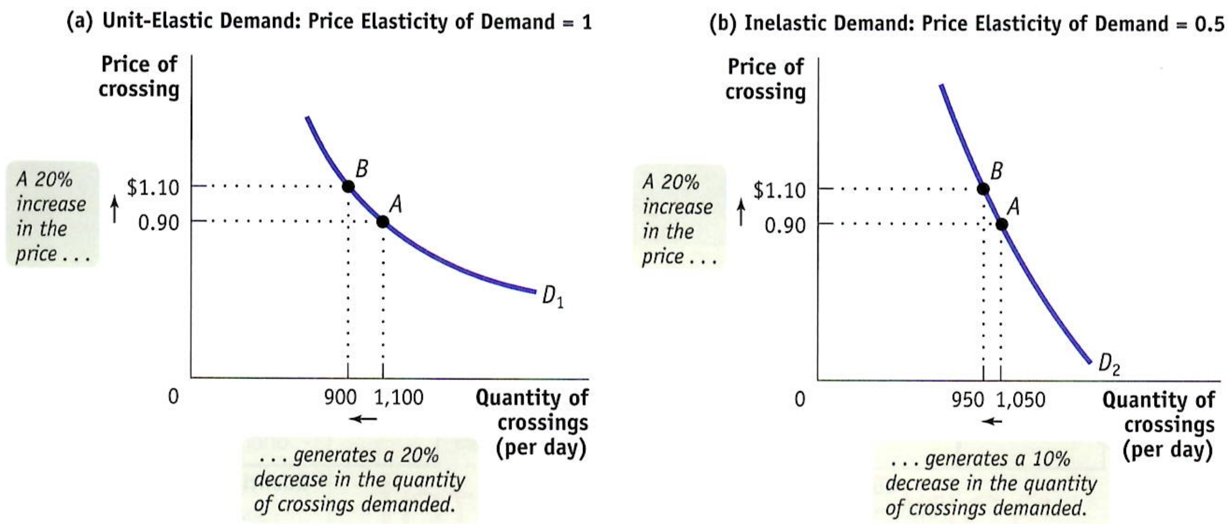
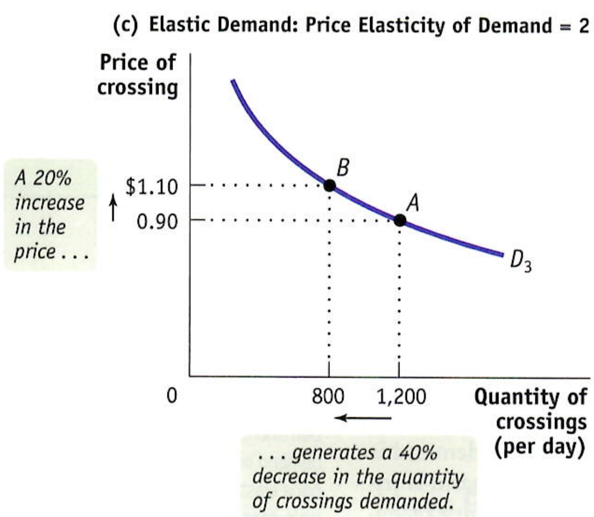
When the Bay Area Toll Authority deliberated a toll increase from $4 to $6 for San Francisco's Bay Bridge in 2010, at issue was the price elasticity of demand, which would determine the resulting drop in use.

figure 11.2 Unit-Elastic Demand, Inelastic Demand, and Elastic Demand





Panel (a) shows a case of unit-elastic demand: a 20% increase in price generates a 20% decline in quantity demanded, implying a price elasticity of demand of 1. Panel (b) shows a case of inelastic demand: a 20% increase in price generates a 10% decline in quantity demanded, implying a price elasticity of demand of 0.5. A case of elastic demand is shown in Panel (c): a 20% increase in price causes a 40% decline in quantity demanded, implying a price elasticity of demand of 2. All percentages are calculated using the midpoint method.

Panel (c) shows a case of elastic demand when the toll is raised from $0.90 to $1.10. The 20% price increase causes the quantity demanded to fall from 1,200 to 800, a 40% decline, so the price elasticity of demand is 40%/20% = 2.

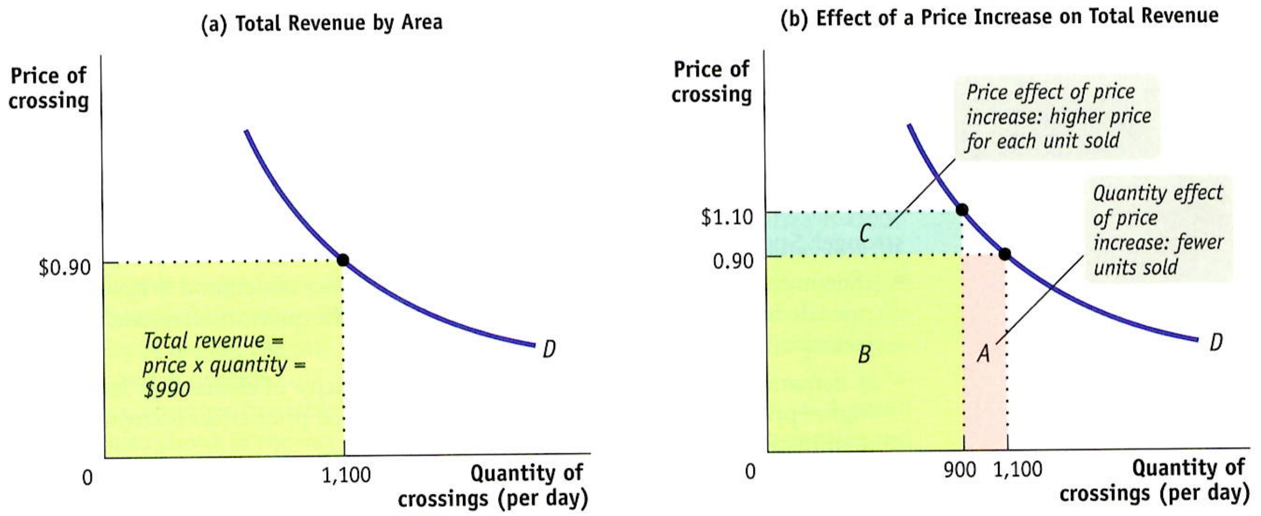
Why does it matter whether demand is unit-elastic, inelastic, or elastic? Because this classification predicts how changes in the price of a good will affect the *total revenue* earned by producers from the sale of that good. In many real-life situations, such as the one faced by Med-Stat, it is crucial to know how price changes affect total revenue. **Total revenue** is defined as the total value of sales of a good or service: the price multiplied by the quantity sold.

$$\textbf{(11-1)} \quad \text{Total revenue} = \text{Price} \times \text{Quantity sold}$$

Total revenue is the total value of sales of a good or service. It is equal to the price multiplied by the quantity sold.

Total revenue has a useful graphical representation that can help us understand why knowing the price elasticity of demand is crucial when we ask whether a price rise will increase or reduce total revenue. Panel (a) of Figure 11.3 shows the same demand curve as panel (a) of Figure 11.2. We see that 1,100 drivers will use the bridge if the toll

figure 11.3 Total Revenue



The green rectangle in panel (a) represents total revenue generated from 1,100 drivers who each pay a toll of $0.90. Panel (b) shows how total revenue is affected when the price increases from $0.90 to $1.10. Due to the quantity effect, total revenue falls by area *A*. Due to the price effect, total revenue increases by area *C*. In general, the overall effect can go either way, depending on the price elasticity of demand.

is $0.90. So the total revenue at a price of $0.90 is $0.90 × 1,100 = $990. This value is equal to the area of the green rectangle, which is drawn with the bottom left corner at the point (0, 0) and the top right corner at (1,100, 0.90). In general, the total revenue at any given price is equal to the area of a rectangle whose height is the price and whose width is the quantity demanded at that price.

To get an idea of why total revenue is important, consider the following scenario. Suppose that the toll on the bridge is currently $0.90 but that the highway department must raise extra money for road repairs. One way to do this is to raise the toll on the bridge. But this plan might backfire, since a higher toll will reduce the number of drivers who use the bridge. And if traffic on the bridge dropped a lot, a higher toll would actually reduce total revenue instead of increasing it. So it's important for the highway department to know how drivers will respond to a toll increase.

We can see graphically how the toll increase affects total bridge revenue by examining panel (b) of Figure 11.3. At a toll of $0.90, total revenue is given by the sum of the areas *A* and *B*. After the toll is raised to $1.10, total revenue is given by the sum of areas *B* and *C*. So when the toll is raised, revenue represented by area *A* is lost but revenue represented by area *C* is gained. These two areas have important interpretations. Area *C* represents the revenue gain that comes from the additional $0.20 paid by drivers who continue to use the bridge. That is, the 900 who continue to use the bridge contribute an additional $0.20 × 900 = $180 per day to total revenue, represented by area *C*. But 200 drivers who would have used the bridge at a price of $0.90 no longer do so, generating a loss to total revenue of $0.90 × 200 = $180 per day, represented by area *A*. (In this particular example, because demand is unit-elastic—the same as in panel (a) of Figure 11.2—the rise in the toll has no effect on total revenue; areas *A* and *B* are the same size.)

Except in the rare case of a good with perfectly elastic or perfectly inelastic demand, when a seller raises the price of a good, two countervailing effects are present:

- *A price effect.* After a price increase, each unit sold sells at a higher price, which tends to raise revenue.
- *A quantity effect.* After a price increase, fewer units are sold, which tends to lower revenue.

But then, you may ask, what is the net ultimate effect on total revenue: does it go up or down? The answer is that, in general, the effect on total revenue can go either way—a price rise may either increase total revenue or lower it. If the price effect, which tends to raise total revenue, is the stronger of the two effects, then total revenue goes up. If the quantity effect, which tends to reduce total revenue, is the stronger, then total revenue goes down. And if the strengths of the two effects are exactly equal—as in our toll bridge example, where a $180 gain offsets a $180 loss—total revenue is unchanged by the price increase.

The price elasticity of demand tells us what happens to total revenue when price changes: its size determines which effect—the price effect or the quantity effect—is stronger. Specifically:

- If demand for a good is *unit-elastic* (the price elasticity of demand is 1), an increase in price does not change total revenue. In this case, the quantity effect and the price effect exactly offset each other.
- If demand for a good is *inelastic* (the price elasticity of demand is less than 1), a higher price increases total revenue. In this case, the price effect is stronger than the quantity effect.
- If demand for a good is *elastic* (the price elasticity of demand is greater than 1), an increase in price reduces total revenue. In this case, the quantity effect is stronger than the price effect.

Table 11.1 shows how the effect of a price increase on total revenue depends on the price elasticity of demand, using the same data as in Figure 11.2. An increase in the price from $0.90 to $1.10 leaves total revenue unchanged at $990 when demand is unit-elastic. When demand is inelastic, the price effect dominates the quantity effect; the same price increase leads to an increase in total revenue from $945 to $1,045. And when demand is elastic, the quantity effect dominates the price effect; the price increase leads to a decline in total revenue from $1,080 to $880.

table **11.1**

Price Elasticity of Demand and Total Revenue

	Price of crossing = $0.90	Price of crossing = $1.10
Unit-elastic demand (price elasticity of demand = 1)		
Quantity demanded	1,100	900
Total revenue	$990	$990
Inelastic demand (price elasticity of demand = 0.5)		
Quantity demanded	1,050	950
Total revenue	$945	$1,045
Elastic demand (price elasticity of demand = 2)		
Quantity demanded	1,200	800
Total revenue	$1,080	$880

The price elasticity of demand also predicts the effect of a *fall* in price on total revenue. When the price falls, the same two countervailing effects are present, but they work in the opposite directions as compared to the case of a price rise. There is the price effect of a lower price per unit sold, which tends to lower revenue. This is countered by the quantity effect of more units sold, which tends to raise revenue. Which effect dominates depends on the price elasticity. Here is a quick summary:

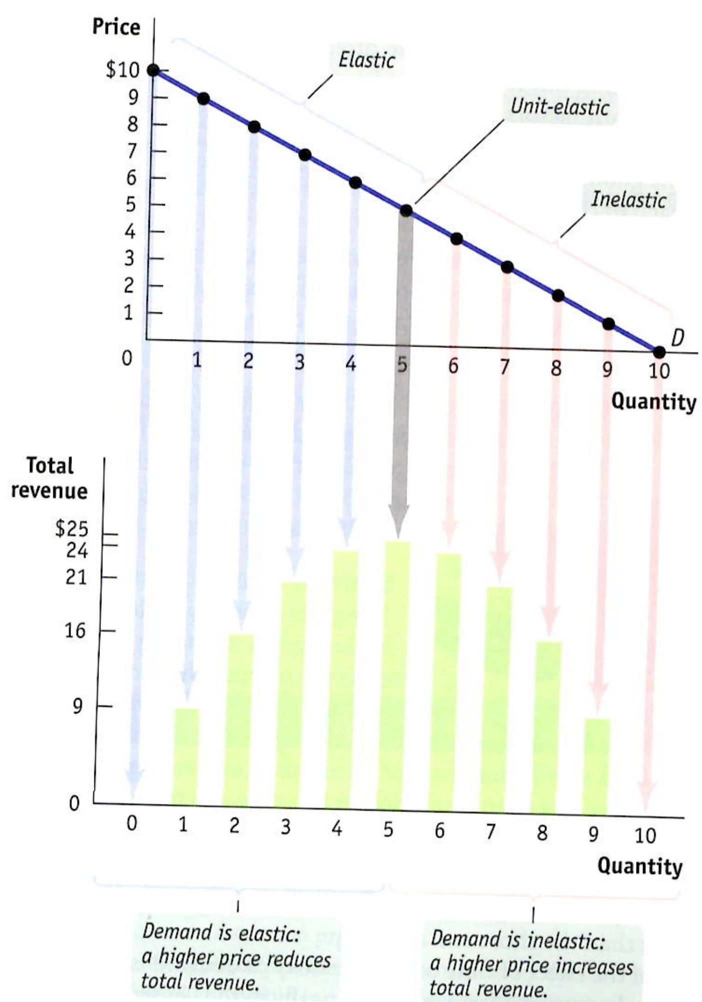
- When demand is *unit-elastic,* the two effects exactly balance each other out; so a fall in price has no effect on total revenue.
- When demand is *inelastic,* the price effect dominates the quantity effect; so a fall in price reduces total revenue.
- When demand is *elastic,* the quantity effect dominates the price effect; so a fall in price increases total revenue.

Price Elasticity Along the Demand Curve

Suppose an economist says that "the price elasticity of demand for coffee is 0.25." What he or she means is that *at the current price* the elasticity is 0.25. In the previous discussion of the toll bridge, what we were really describing was the elasticity *at the price* of $0.90. Why this qualification? Because for the vast majority of demand curves, the price elasticity of demand at one point along the curve is different from the price elasticity of demand at other points along the same curve.

To see this, consider the table in Figure 11.4, which shows a hypothetical demand schedule. It also shows in the last column the total revenue generated at each price and quantity combination in the demand schedule. The upper panel of the graph in Figure

figure 11.4 The Price Elasticity of Demand Changes Along the Demand Curve



Demand Schedule and Total Revenue for a Linear Demand Curve

Price	Quantity demanded	Total revenue
$0	10	$0
1	9	9
2	8	16
3	7	21
4	6	24
5	5	25
6	4	24
7	3	21
8	2	16
9	1	9
10	0	0

The upper panel shows a demand curve corresponding to the demand schedule in the table. The lower panel shows how total revenue changes along that demand curve: at each price and quantity combination, the height of the bar represents the total revenue generated. You can see that at a low price, raising the price increases total revenue. So demand is inelastic at low prices. At a high price, however, a rise in price reduces total revenue. So demand is elastic at high prices.

11.4 shows the corresponding demand curve. The lower panel illustrates the same data on total revenue: the height of a bar at each quantity demanded—which corresponds to a particular price—measures the total revenue generated at that price.

In Figure 11.4, you can see that when the price is low, raising the price increases total revenue: starting at a price of $1, raising the price to $2 increases total revenue from $9 to $16. This means that when the price is low, demand is inelastic. Moreover, you can see that demand is inelastic on the entire section of the demand curve from a price of $0 to a price of $5.

When the price is high, however, raising it further reduces total revenue: starting at a price of $8, for example, raising the price to $9 reduces total revenue, from $16 to $9. This means that when the price is high, demand is elastic. Furthermore, you can see that demand is elastic over the section of the demand curve from a price of $5 to $10.

For the vast majority of goods, the price elasticity of demand changes along the demand curve. So whenever you measure a good's elasticity, you are really measuring it at a particular point or section of the good's demand curve.

What Factors Determine the Price Elasticity of Demand?

The flu vaccine shortfall of 2004–2005 allowed vaccine distributors to significantly raise their prices for two important reasons: there were no substitutes, and for many people the vaccine was a medical necessity. People responded in various ways. Some paid the high prices, and some traveled to Canada and other countries to get vaccinated. Some simply did without (and over time often changed their habits to avoid catching the flu, such as eating out less often and avoiding mass transit). This experience illustrates the four main factors that determine elasticity: whether close substitutes are available, whether the good is a necessity or a luxury, the share of income a consumer spends on the good, and how much time has elapsed since the price change. We'll briefly examine each of these factors.

Whether Close Substitutes Are Available The price elasticity of demand tends to be high if there are other goods that consumers regard as similar and would be willing to consume instead. The price elasticity of demand tends to be low if there are no close substitutes.

Whether the Good Is a Necessity or a Luxury The price elasticity of demand tends to be low if a good is something you must have, like a life-saving medicine. The price elasticity of demand tends to be high if the good is a luxury—something you can easily live without.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Share of Income Spent on the Good The price elasticity of demand tends to be low when spending on a good accounts for a small share of a consumer's income. In that case, a significant change in the price of the good has little impact on how much the consumer spends. In contrast, when a good accounts for a significant share of a consumer's spending, the consumer is likely to be very responsive to a change in price. In this case, the price elasticity of demand is high.

Time In general, the price elasticity of demand tends to increase as consumers have more time to adjust to a price change. This means that the long-run price elasticity of demand is often higher than the short-run elasticity.

A good illustration of the effect of time on the elasticity of demand is drawn from the 1970s, the first time gasoline prices increased dramatically in the United States. Initially, consumption fell very little because there were no close substitutes for gasoline and because driving their cars was necessary for people to carry out the ordinary tasks of life. Over time, however, Americans changed their habits in ways that enabled them to gradually reduce their gasoline consumption. The result was a steady decline in gasoline consumption over the next decade, even though the price of gasoline did not continue to rise, confirming that the long-run price elasticity of demand for gasoline was indeed much larger than the short-run elasticity.

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Responding to Your Tuition Bill

College costs more than ever—and not just because of overall inflation. Tuition has been rising faster than the overall cost of living for years. But does rising tuition keep people from going to college? Two studies found that the answer depends on the type of college. Both studies assessed how responsive the decision to go to college is to a change in tuition.

A 1988 study found that a 3% increase in tuition led to an approximately 2% fall in the number of students enrolled at four-year institutions, giving a price elasticity of demand of 0.67 (2%/3%). In the case of two-year institutions, the study found a significantly higher response: a 3% increase in tuition led to a 2.7% fall in enrollments, giving a price elasticity of demand of 0.9. In other words, the enrollment decision for students at two-year colleges was significantly more responsive to price than for students at four-year colleges. The result: students at two-year colleges are more likely to forgo getting a degree because of tuition costs than students at four-year colleges.

A 1999 study confirmed this pattern. In comparison to four-year colleges, it found that two-year college enrollment rates were significantly more responsive to changes in state financial aid (a decline in aid leading to a decline in enrollments), a predictable effect given these students' greater sensitivity to the cost of tuition. Another piece of evidence suggests that students at two-year colleges are more likely to be paying their own way and making a trade-off between attending college and working: the study found that enrollments at two-year colleges are much more responsive to changes in the unemployment rate (an increase in the unemployment rate leading to an increase in enrollments) than enrollments at four-year colleges. So is the cost of tuition a barrier to getting a college degree in the United States? Yes, but more so at two-year colleges than at four-year colleges.

Interestingly, the 1999 study found that for both two-year and four-year colleges, price sensitivity of demand had fallen somewhat since the 1988 study. One possible explanation is that because the value of a college education has risen considerably over time, fewer people forgo college, even if tuition goes up. (See source note on copyright page.)

Module 11 AP Review

Solutions appear at the back of the book.

Check Your Understanding

1. For each case, choose the condition that characterizes demand: elastic demand, inelastic demand, or unit-elastic demand.
   a. Total revenue decreases when price increases.
   b. When price falls, the additional revenue generated by the increase in the quantity sold is exactly offset by the revenue lost from the fall in the price received per unit.
   c. Total revenue falls when output increases.
   d. Producers in an industry find they can increase their total revenues by working together to reduce industry output.
2. For the following goods, is demand elastic, inelastic, or unit-elastic? Explain. What is the shape of the demand curve?
   a. demand by a snake-bite victim for an antidote
   b. demand by students for blue pencils

Module 12 Other Elasticities

What you will learn in this Module:

- How the cross-price elasticity of demand measures the responsiveness of demand for one good to changes in the price of another good
- The meaning and importance of the income elasticity of demand, a measure of the responsiveness of demand to changes in income
- The significance of the price elasticity of supply, which measures the responsiveness of the quantity supplied to changes in price
- The factors that influence the size of these various elasticities

Other Elasticities

We stated earlier that economists use the concept of *elasticity* to measure the responsiveness of one variable to changes in another. However, up to this point we have focused on the price elasticity of demand. Now that we have used elasticity to measure the responsiveness of quantity demanded to changes in price, we can go on to look at how elasticity is used to understand the relationship between other important variables in economics.

The quantity of a good demanded depends not only on the price of that good but also on other variables. In particular, demand curves shift because of changes in the prices of related goods and changes in consumers' incomes. It is often important to have a measure of these other effects, and the best measures are—you guessed it—elasticities. Specifically, we can best measure how the demand for a good is affected by prices of other goods using a measure called the *cross-price elasticity of demand,* and we can best measure how demand is affected by changes in income using the *income elasticity of demand.*

Finally, we can also use elasticity to measure supply responses. The *price elasticity of supply* measures the responsiveness of the quantity supplied to changes in price.

The Cross-Price Elasticity of Demand

The demand for a good is often affected by the prices of other, related goods—goods that are substitutes or complements. A change in the price of a related good shifts the demand curve of the original good, reflecting a change in the quantity demanded at any given price. The strength of such a "cross" effect on demand can be measured by the **cross-price elasticity of demand,** defined as the ratio of the percent change in the quantity demanded of one good to the percent change in the price of another.

The **cross-price elasticity of demand** between two goods measures the effect of the change in one good's price on the quantity demanded of the other good. It is equal to the percent change in the quantity demanded of one good divided by the percent change in the other good's price.

(12-1) Cross-price elasticity of demand between goods A and B

$$= \frac{\text{\% change in quantity of A demanded}}{\text{\% change in price of B}}$$

When two goods are substitutes, like hot dogs and hamburgers, the cross-price elasticity of demand is positive: a rise in the price of hot dogs increases the demand for hamburgers—that is, it causes a rightward shift of the demand curve for hamburgers. If the goods are close substitutes, the cross-price elasticity will be positive and large;

if they are not close substitutes, the cross-price elasticity will be positive and small. So when the cross-price elasticity of demand is positive, its size is a measure of how closely substitutable the two goods are.

When two goods are complements, like hot dogs and hot dog buns, the cross-price elasticity is negative: a rise in the price of hot dogs decreases the demand for hot dog buns—that is, it causes a leftward shift of the demand curve for hot dog buns. As with substitutes, the size of the cross-price elasticity of demand between two complements tells us how strongly complementary they are: if the cross-price elasticity is only slightly below zero, they are weak complements; if it is very negative, they are strong complements.

Note that in the case of the cross-price elasticity of demand, the sign (plus or minus) is very important: it tells us whether the two goods are complements or substitutes. So we cannot drop the minus sign as we did for the price elasticity of demand.

Our discussion of the cross-price elasticity of demand is a useful place to return to a point we made earlier: elasticity is a *unit-free* measure—that is, it doesn't depend on the units in which goods are measured.

To see the potential problem, suppose someone told you that "if the price of hot dog buns rises by \$0.30, Americans will buy 10 million fewer hot dogs this year." If you've ever bought hot dog buns, you'll immediately wonder: is that a \$0.30 increase in the price *per bun,* or is it a \$0.30 increase in the price *per package* of buns? It makes a big difference what units we are talking about! However, if someone says that the cross-price elasticity of demand between buns and hot dogs is −0.3, it doesn't matter whether buns are sold individually or by the package. So elasticity is defined as a ratio of percent changes, which avoids confusion over units.

The Income Elasticity of Demand

The **income elasticity of demand** measures how changes in income affect the demand for a good. It indicates whether a good is normal or inferior and specifies how responsive demand for the good is to changes in income. Having learned the price and cross-price elasticity formulas, the income elasticity formula will look familiar:

$$\textbf{(12-2)}\quad \text{Income elasticity of demand} = \frac{\%\text{ change in quantity demanded}}{\%\text{ change in income}}$$

Just as the cross-price elasticity of demand between two goods can be either positive or negative, depending on whether the goods are substitutes or complements, the income elasticity of demand for a good can also be either positive or negative. Recall that goods can be either *normal goods,* for which demand increases when income rises, or *inferior goods,* for which demand decreases when income rises. These definitions relate directly to the sign of the income elasticity of demand:

- When the income elasticity of demand is positive, the good is a normal good—that is, the quantity demanded at any given price increases as income increases.
- When the income elasticity of demand is negative, the good is an inferior good—that is, the quantity demanded at any given price decreases as income increases.

Economists often use estimates of the income elasticity of demand to predict which industries will grow most rapidly as the incomes of consumers grow over time. In doing this, they often find it useful to make a further distinction among normal goods, identifying which are *income-elastic* and which are *income-inelastic.*

The demand for a good is **income-elastic** if the income elasticity of demand for that good is greater than 1. When income rises, the demand for income-elastic goods rises *faster* than income. Luxury goods such as second homes and international travel tend to be income-elastic. The demand for a good is **income-inelastic** if the income elasticity of demand for that good is positive but less than 1. When income rises, the demand for income-inelastic goods rises, but more slowly than income. Necessities such as food and clothing tend to be income-inelastic.

The **income elasticity of demand** is the percent change in the quantity of a good demanded when a consumer's income changes divided by the percent change in the consumer's income.

The demand for a good is **income-elastic** if the income elasticity of demand for that good is greater than 1.

The demand for a good is **income-inelastic** if the income elasticity of demand for that good is positive but less than 1.

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Where Have All the Farmers Gone?

What percentage of Americans live on farms? Sad to say, the U.S. government no longer publishes that number. In 1991 the official percentage was 1.9, but in that year the government decided it was no longer a meaningful indicator of the size of the agricultural sector because a large proportion of those who live on farms actually make their living doing something else. But in the days of the Founding Fathers, the great majority of Americans lived on farms. As recently as the 1940s, one American in six—or approximately 17%—still did.

Why do so few people now live and work on farms in the United States? There are two main reasons, both involving elasticities.

First, the income elasticity of demand for food is much less than 1—food demand is income-inelastic. As consumers grow richer, other things equal, spending on food rises less than in proportion to income. As a result, as the U.S. economy has grown, the share of income spent on food—and therefore the share of total U.S. income earned by farmers—has fallen.

Second, agriculture has been a technologically progressive sector for approximately 150 years in the United States, with steadily increasing yields over time. You might think that technological progress would be good for farmers. But competition among farmers means that technological progress leads to lower food prices. Meanwhile, the demand for food is price-inelastic, so falling prices of agricultural goods, other things equal, reduce the total revenue of farmers. That's right: progress in farming is good for consumers but bad for farmers.

The combination of these effects explains the relative decline of farming. Even if farming weren't such a technologically progressive sector, the low income elasticity of demand for food would ensure that the income of farmers grows more slowly than the economy as a whole. The combination of rapid technological progress in farming with price-inelastic demand for farm products reinforces this effect, further reducing the growth of farm income. In short, the U.S. farm sector has been a victim of success—the U.S. economy's success as a whole (which reduces the importance of spending on food) and its own success in increasing yields.

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The Price Elasticity of Supply

In the wake of the flu vaccine shortfall of 2004, attempts by vaccine distributors to drive up the price of vaccines would have been much less effective if a higher price had induced a large increase in the output of flu vaccines by flu vaccine manufacturers other than Chiron. In fact, if the rise in price had precipitated a significant increase in flu vaccine production, the price would have been pushed back down. But that didn't happen because, as we mentioned earlier, it would have been far too costly and technically difficult to produce more vaccine for the 2004–2005 flu season. (In reality, the production of flu vaccine is begun a year before it is to be distributed.) This was another critical element in the ability of some flu vaccine distributors, like Med-Stat, to get significantly higher prices for their product: a low responsiveness in the quantity of output supplied to the higher price of flu vaccine by flu vaccine producers. To measure the response of producers to price changes, we need a measure parallel to the price elasticity of demand—the *price elasticity of supply.*

Measuring the Price Elasticity of Supply

The **price elasticity of supply** is defined the same way as the price elasticity of demand (although there is no minus sign to be eliminated here):

$$\textbf{(12-3)}\quad \text{Price elasticity of supply} = \frac{\%\ \text{change in quantity supplied}}{\%\ \text{change in price}}$$

The only difference is that here we consider movements along the supply curve rather than movements along the demand curve.

Suppose that the price of tomatoes rises by 10%. If the quantity of tomatoes supplied also increases by 10% in response, the price elasticity of supply of tomatoes is

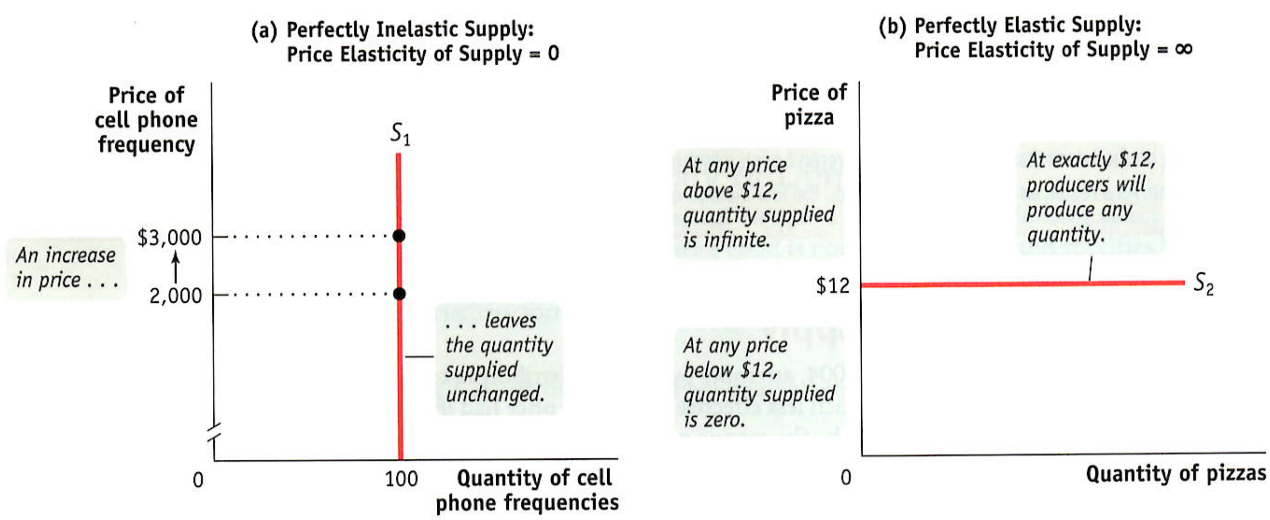
The **price elasticity of supply** is a measure of the responsiveness of the quantity of a good supplied to the price of that good. It is the ratio of the percent change in the quantity supplied to the percent change in the price as we move along the supply curve.

There is **perfectly inelastic supply** when the price elasticity of supply is zero, so that changes in the price of the good have no effect on the quantity supplied. A perfectly inelastic supply curve is a vertical line.

1 (10%/10%) and supply is unit-elastic. If the quantity supplied increases by 5%, the price elasticity of supply is 0.5 and supply is inelastic; if the quantity increases by 20%, the price elasticity of supply is 2 and supply is elastic.

As in the case of demand, the extreme values of the price elasticity of supply have a simple graphical representation. Panel (a) of Figure 12.1 shows the supply of cell phone frequencies, the portion of the radio spectrum that is suitable for sending and receiving cell phone signals. Governments own the right to sell the use of this part of the radio spectrum to cell phone operators inside their borders. But governments can't increase or decrease the number of cell phone frequencies they have to offer—for technical reasons, the quantity of frequencies suitable for cell phone operation is fixed. So the supply curve for cell phone frequencies is a vertical line, which we have assumed is set at the quantity of 100 frequencies. As you move up and down that curve, the change in the quantity supplied by the government is zero, whatever the change in price. So panel (a) illustrates a case of **perfectly inelastic supply,** meaning that the price elasticity of supply is zero.

figure 12.1 **Two Extreme Cases of Price Elasticity of Supply**



Panel (a) shows a perfectly inelastic supply curve, which is a vertical line. The price elasticity of supply is zero: the quantity supplied is always the same, regardless of price. Panel (b) shows a perfectly elastic supply curve, which is a horizontal line. At a price of $12, producers will supply any quantity, but they will supply none at a price below $12. If the price rises above $12, they will supply an extremely large quantity.

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Panel (b) shows the supply curve for pizza. We suppose that it costs $12 to produce a pizza, including all opportunity costs. At any price below $12, it would be unprofitable to produce pizza and all the pizza parlors would go out of business. At a price of $12 or more, there are many producers who could operate pizza parlors. The ingredients—flour, tomatoes, cheese—are plentiful. And if necessary, more tomatoes could be grown, more milk could be produced to make mozzarella cheese, and so on. So by allowing profits, any price above $12 would elicit the supply of an extremely large quantity of pizzas. The implied supply curve is therefore a horizontal line at $12. Since even a tiny increase in the price would lead to an enormous increase in the quantity supplied, the price elasticity of supply would be virtually infinite. A horizontal supply curve such as this represents a case of **perfectly elastic supply.**

As our cell phone frequencies and pizza examples suggest, real-world instances of both perfectly inelastic and perfectly elastic supply are easier to find than their counterparts in demand.

There is **perfectly elastic supply** if the quantity supplied is zero below some price and infinite above that price. A perfectly elastic supply curve is a horizontal line.

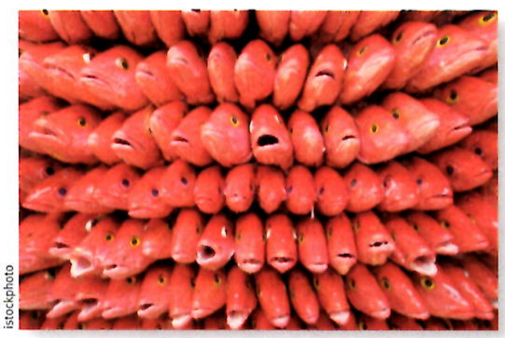
What Factors Determine the Price Elasticity of Supply? Our examples tell us the main determinant of the price elasticity of supply: the availability of inputs. In addition, as with the price elasticity of demand, time may also play a role in the price elasticity of supply. Here we briefly summarize the two factors.

The Availability of Inputs The price elasticity of supply tends to be large when inputs are readily available and can be shifted into and out of production at a relatively low cost. It tends to be small when inputs are available only in a more-or-less fixed quantity or can be shifted into and out of production only at a relatively high cost.

Time The price elasticity of supply tends to grow larger as producers have more time to respond to a price change. This means that the long-run price elasticity of supply is often higher than the short-run elasticity. In the case of the flu vaccine shortfall, time was the crucial element because flu vaccine must be grown in cultures over many months.

The price elasticity of pizza supply is very high because the inputs needed to make more pizza are readily available. The price elasticity of cell phone frequencies is zero because an essential input—the radio spectrum—cannot be increased at all.

Many industries are like pizza and have large price elasticities of supply: they can be readily expanded because they don't require any special or unique resources. On the other hand, the price elasticity of supply is usually substantially less than perfectly elastic for goods that involve limited natural resources: minerals like gold or copper, agricultural products like coffee that flourish only on certain types of land, and renewable resources like ocean fish that can be exploited only up to a point without destroying the resource.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But given enough time, producers are often able to significantly change the amount they produce in response to a price change, even when production involves a limited natural resource. For example, consider again the effects of a surge in flu vaccine prices, but this time focus on the supply response. If the price were to rise to $90 per vaccination and stay there for a number of years, there would almost certainly be a substantial increase in flu vaccine production. Producers such as Chiron would eventually respond by increasing the size of their manufacturing plants, hiring more lab technicians, and so on. But significantly enlarging the capacity of a biotech manufacturing lab takes several years, not weeks or months or even a single year.

For this reason, economists often make a distinction between the short-run elasticity of supply, usually referring to a few weeks or months, and the long-run elasticity of supply, usually referring to several years. In most industries, the long-run elasticity of supply is larger than the short-run elasticity.

An Elasticity Menagerie

We've just run through quite a few different types of elasticity. Keeping them all straight can be a challenge. So in Table 12.1 on the next page we provide a summary of all the types of elasticity we have discussed and their implications.

table 12.1

An Elasticity Menagerie

Name	Possible values	Significance
Price elasticity of demand $= \dfrac{\%\text{ change in quantity demanded}}{\%\text{ change in price}}$ (dropping the minus sign)		
Perfectly inelastic demand	0	Price has no effect on quantity demanded (vertical demand curve).
Inelastic demand	Between 0 and 1	A rise in price increases total revenue.
Unit-elastic demand	Exactly 1	Changes in price have no effect on total revenue.
Elastic demand	Greater than 1, less than ∞	A rise in price reduces total revenue.
Perfectly elastic demand	∞	A rise in price causes quantity demanded to fall to 0. A fall in price leads to an infinite quantity demanded (horizontal demand curve).
Cross-price elasticity of demand $= \dfrac{\%\text{ change in quantity \textit{of one good} demanded}}{\%\text{ change in price \textit{of another good}}}$		
Complements	Negative	Quantity demanded of one good falls when the price of another rises.
Substitutes	Positive	Quantity demanded of one good rises when the price of another rises.
Income elasticity of demand $= \dfrac{\%\text{ change in quantity demanded}}{\%\text{ change in income}}$		
Inferior good	Negative	Quantity demanded falls when income rises.
Normal good, income-inelastic	Positive, less than 1	Quantity demanded rises when income rises, but not as rapidly as income.
Normal good, income-elastic	Greater than 1	Quantity demanded rises when income rises, and more rapidly than income.
Price elasticity of supply $= \dfrac{\%\text{ change in quantity supplied}}{\%\text{ change in price}}$		
Perfectly inelastic supply	0	Price has no effect on quantity supplied (vertical supply curve).
	Greater than 0, less than ∞	Ordinary upward-sloping supply curve.
Perfectly elastic supply	∞	Any fall in price causes quantity supplied to fall to 0. Any rise in price elicits an infinite quantity supplied (horizontal supply curve).

Module 12 AP Review

Solutions appear at the back of the book.

Check Your Understanding

1. After Chelsea's income increased from $12,000 to $18,000 a year, her purchases of CDs increased from 10 to 40 CDs a year. Calculate Chelsea's income elasticity of demand for CDs using the midpoint method.

2. As the price of margarine rises by 20%, a manufacturer of baked goods increases its quantity of butter demanded by 5%. Calculate the cross-price elasticity of demand between butter and margarine. Are butter and margarine substitutes or complements for this manufacturer?

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