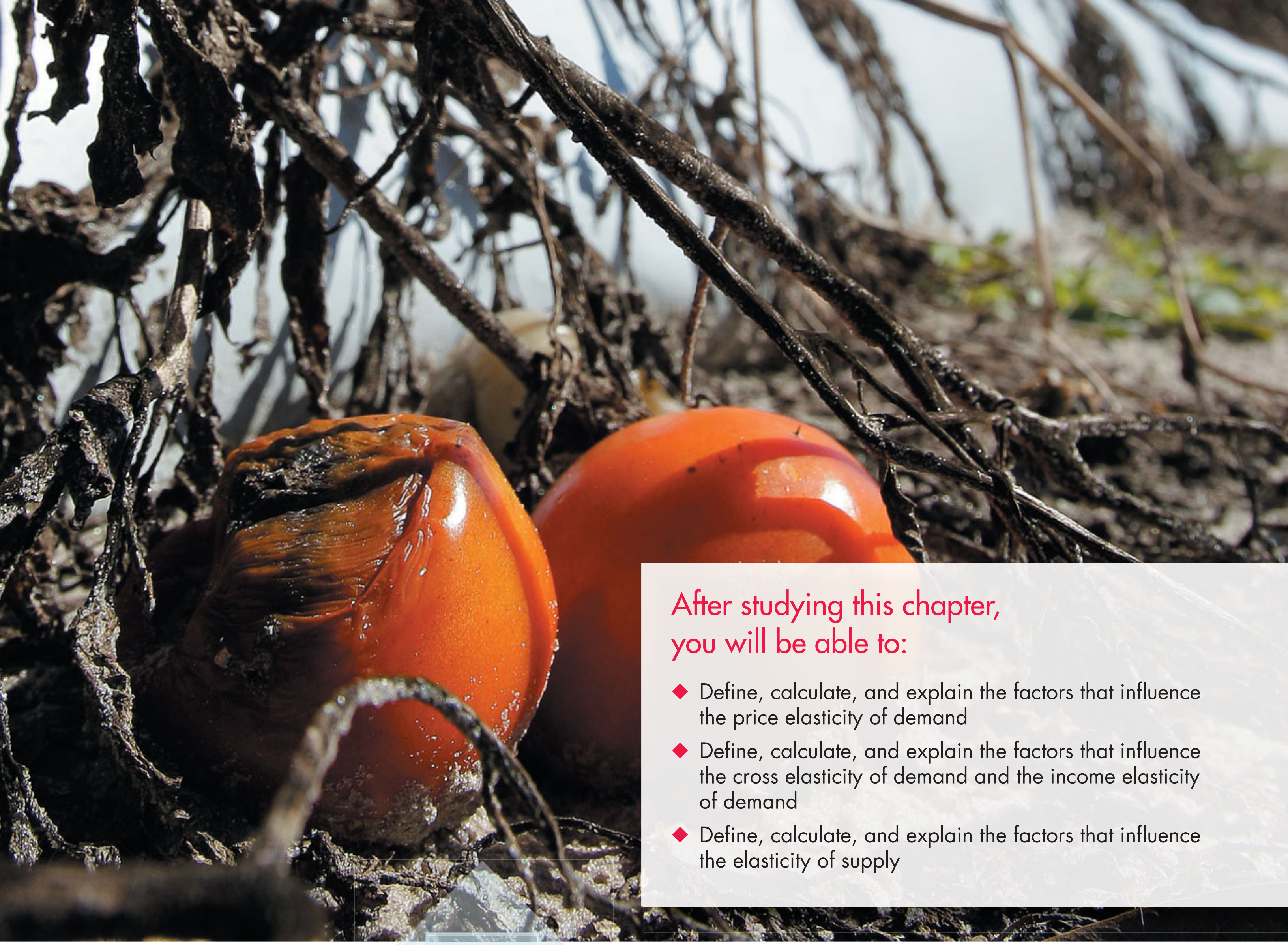


## After studying this chapter, you will be able to:

- Define, calculate, and explain the factors that influence the price elasticity of demand
- Define, calculate, and explain the factors that influence the cross elasticity of demand and the income elasticity of demand
- Define, calculate, and explain the factors that influence the elasticity of supply

# 4

# ELASTICITY

**What do you do when the price of gasoline soars to $3 a gallon? If you're** like most people, you complain a lot but keep on filling your tank and spending more on gas. Would you react the same way to a rise in the price of tomatoes? In the winter of 2010, a prolonged Florida frost wiped out most of the state's tomato crop, driving the price of tomatoes to almost five times its normal level. If faced with this price rise, do you keep buying the same quantity of tomatoes, or do you find less costly substitutes?

How can we compare the effects of price changes on buying plans for different goods such as gasoline and tomatoes?

This chapter introduces you to elasticity: a tool that addresses the quantitative questions like the ones you've just considered and enables us to compare the sensitivity of the quantity demanded to a change in price regardless of the units in which the good is measured.

At the end of the chapter, in Reading Between the Lines, we'll use the concepts of the elasticity of demand and the elasticity of supply to explain what was happening in the market for fresh winter tomatoes from Florida during the severe winter of 2010. But we'll begin by explaining elasticity in another familiar setting: the market for pizza.

## Price Elasticity of Demand

You know that when supply increases, the equilibrium price falls and the equilibrium quantity increases. But does the price fall by a large amount and the quantity increase by a little? Or does the price barely fall and the quantity increase by a large amount?

The answer depends on the responsiveness of the quantity demanded to a change in price. You can see why by studying Fig. 4.1, which shows two possible scenarios in a local pizza market. Figure 4.1(a) shows one scenario, and Fig. 4.1(b) shows the other.

In both cases, supply is initially $S_0$. In part (a), the demand for pizza is shown by the demand curve $D_A$. In part (b), the demand for pizza is shown by the demand curve $D_B$. Initially, in both cases, the price is $20 a pizza and the equilibrium quantity is 10 pizzas an hour.

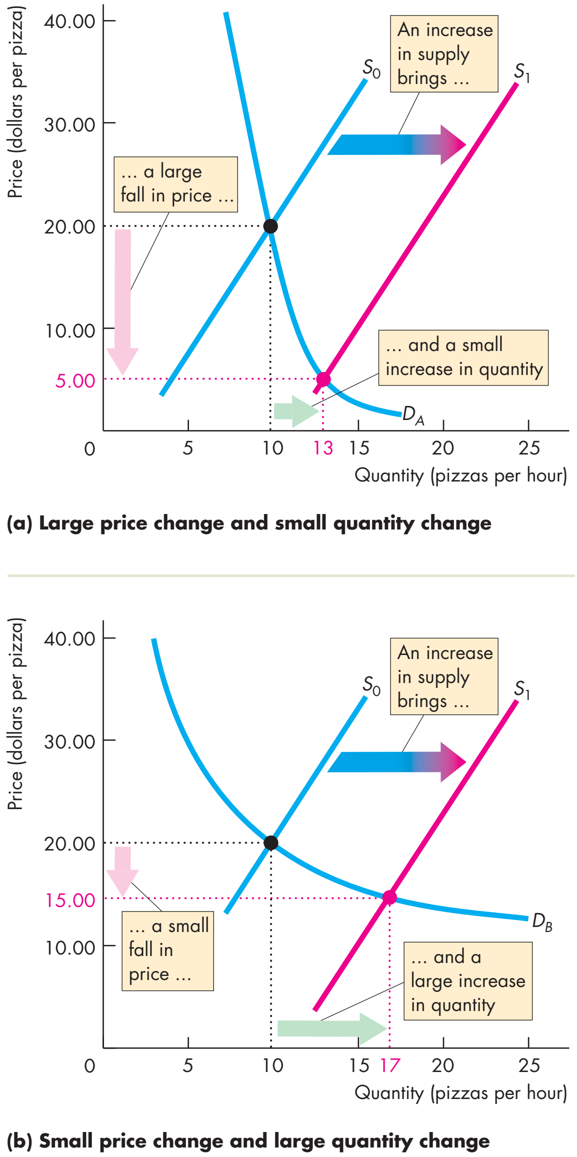
Now a large pizza franchise opens up, and the supply of pizza increases. The supply curve shifts rightward to $S_1$. In case (a), the price falls by an enormous $15 to $5 a pizza, and the quantity increases by only 3 to 13 pizzas an hour. In contrast, in case (b), the price falls by only $5 to $15 a pizza and the quantity increases by 7 to 17 pizzas an hour.

The different outcomes arise from differing degrees of responsiveness of the quantity demanded to a change in price. But what do we mean by responsiveness? One possible answer is slope. The slope of demand curve $D_A$ is steeper than the slope of demand curve $D_B$.

In this example, we can compare the slopes of the two demand curves, but we can't always make such a comparison. The reason is that the slope of a demand curve depends on the units in which we measure the price and quantity. And we often must compare the demand for different goods and services that are measured in unrelated units. For example, a pizza producer might want to compare the demand for pizza with the demand for soft drinks. Which quantity demanded is more responsive to a price change? This question can't be answered by comparing the slopes of two demand curves. The units of measurement of pizza and soft drinks are unrelated. The question can be answered with a measure of responsiveness that is independent of units of measurement. Elasticity is such a measure.

The **price elasticity of demand** is a units-free measure of the responsiveness of the quantity demanded of a good to a change in its price when all other influences on buying plans remain the same.

**FIGURE 4.1** How a Change in Supply Changes Price and Quantity




Initially, the price is $20 a pizza and the quantity sold is 10 pizzas an hour. Then supply increases from $S_0$ to $S_1$. In part (a), the price falls by $15 to $5 a pizza, and the quantity increases by 3 to 13 pizzas an hour. In part (b), the price falls by only $5 to $15 a pizza, and the quantity increases by 7 to 17 pizzas an hour. The price change is smaller and the quantity change is larger in case (b) than in case (a). The quantity demanded is more responsive to the change in the price in case (b) than in case (a).

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## Calculating Price Elasticity of Demand

We calculate the *price elasticity of demand* by using the formula:

$$\text{Price elasticity of demand} = \frac{\text{Percentage change in quantity demanded}}{\text{Percentage change in price}}.$$

To calculate the price elasticity of demand for pizza, we need to know the quantity demanded of pizza at two different prices, when all other influences on buying plans remain the same.

Figure 4.2 zooms in on the demand curve for pizza and shows how the quantity demanded responds to a small change in price. Initially, the price is $20.50 a pizza and 9 pizzas an hour are demanded—the original point. The price then falls to $19.50 a pizza, and the quantity demanded increases to 11 pizzas an hour—the new point. When the price falls by $1 a pizza, the quantity demanded increases by 2 pizzas an hour.

To calculate the price elasticity of demand, we express the change in price as a percentage of the *average price* and the change in the quantity demanded as a percentage of the *average quantity*. By using the average price and average quantity, we calculate the elasticity at a point on the demand curve midway between the original point and the new point.

The original price is $20.50 and the new price is $19.50, so the price change is $1 and the average price is $20 a pizza. Call the percentage change in the price $\%\Delta P$, then

$$\%\Delta P = \Delta P/P_{ave} \times 100 = (\$1/\$20) \times 100 = 5\%.$$

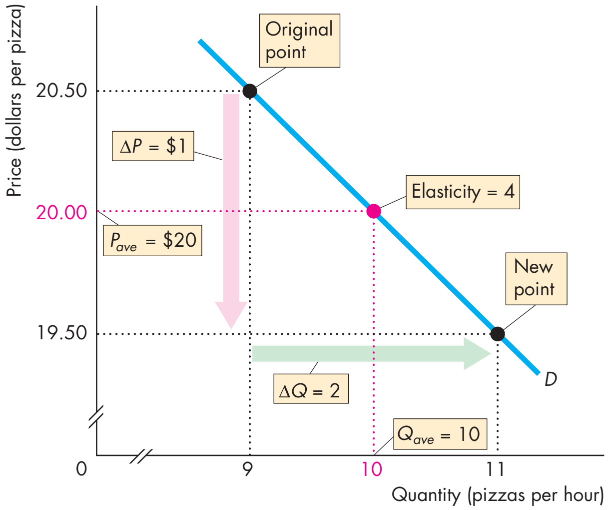
The original quantity demanded is 9 pizzas and the new quantity demanded is 11 pizzas, so the quantity change is 2 pizzas and the average quantity demanded is 10 pizzas. Call the percentage change in the quantity demanded $\%\Delta Q$, then

$$\%\Delta Q = \Delta Q/Q_{ave} \times 100 = (2/10) \times 100 = 20\%.$$

The price elasticity of demand equals the percentage change in the quantity demanded (20 percent) divided by the percentage change in price (5 percent) and is 4. That is,

$$\text{Price elasticity of demand} = \frac{\%\Delta Q}{\%\Delta P} = \frac{20\%}{5\%} = 4.$$

**FIGURE 4.2** Calculating the Elasticity of Demand




The elasticity of demand is calculated by using the formula:*

$$\text{Price elasticity of demand} = \frac{\text{Percentage change in quantity demanded}}{\text{Percentage change in price}} = \frac{\%\Delta Q}{\%\Delta P} = \frac{\Delta Q/Q_{ave}}{\Delta P/P_{ave}} = \frac{2/10}{1/20} = 4.$$

This calculation measures the elasticity at an average price of $20 a pizza and an average quantity of 10 pizzas an hour.

* In the formula, the Greek letter delta (Δ) stands for "change in" and %Δ stands for "percentage change in."

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**Average Price and Quantity** Notice that we use the *average* price and *average* quantity. We do this because it gives the most precise measurement of elasticity—at the midpoint between the original price and the new price. If the price falls from $20.50 to $19.50, the $1 price change is 4.9 percent of $20.50. The 2 pizza change in quantity is 22.2 percent of 9 pizzas, the original quantity. So if we use these numbers, the price elasticity of demand is 22.2 divided by 4.9, which equals 4.5. If the price rises from \$19.50 to \$20.50, the \$1 price change is 5.1 percent of \$19.50. The 2 pizza change in quantity is 18.2 percent of 11 pizzas, the original quantity. So if we use these numbers, the price elasticity of demand is 18.2 divided by 5.1, which equals 3.6.

By using percentages of the *average* price and *average* quantity, we get the same value for the elasticity regardless of whether the price falls from \$20.50 to \$19.50 or rises from \$19.50 to \$20.50.

**Percentages and Proportions** Elasticity is the ratio of two percentage changes, so when we divide one percentage change by another, the 100s cancel. A percentage change is a *proportionate* change multiplied by 100. The proportionate change in price is $\Delta P/P_{ave}$, and the proportionate change in quantity demanded is $\Delta Q/Q_{ave}$. So if we divide $\Delta Q/Q_{ave}$ by $\Delta P/P_{ave}$ we get the same answer as we get by using percentage changes.

**A Units-Free Measure** Now that you've calculated a price elasticity of demand, you can see why it is a *units-free measure*. Elasticity is a units-free measure because the percentage change in each variable is independent of the units in which the variable is measured. The ratio of the two percentages is a number without units.

**Minus Sign and Elasticity** When the price of a good *rises*, the quantity demanded *decreases*. Because a *positive* change in price brings a *negative* change in the quantity demanded, the price elasticity of demand is a negative number. But it is the magnitude, or *absolute value*, of the price elasticity of demand that tells us how responsive the quantity demanded is. So to compare price elasticities of demand, we use the *magnitude* of the elasticity and ignore the minus sign.

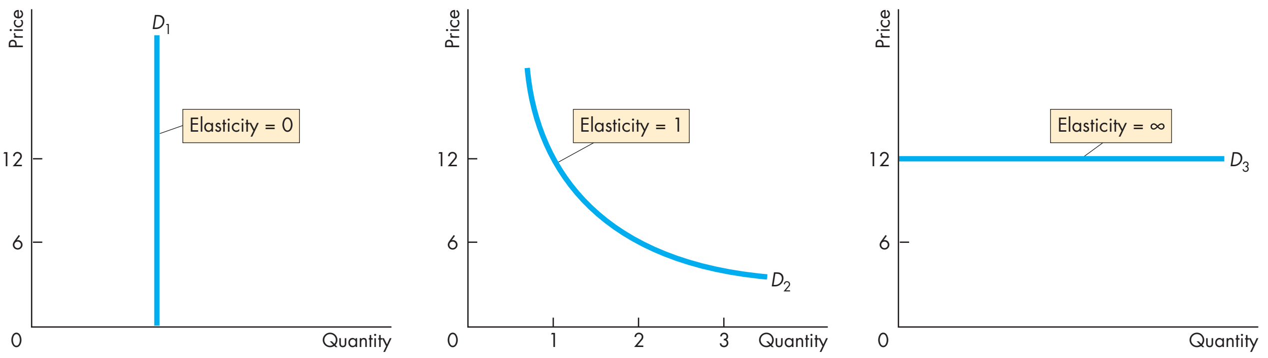
## Inelastic and Elastic Demand

Figure 4.3 shows three demand curves that cover the entire range of possible elasticities of demand. In Fig. 4.3(a), the quantity demanded is constant regardless of the price. If the quantity demanded remains constant when the price changes, then the price elasticity of demand is zero and the good is said to have a **perfectly inelastic demand**. One good that has a very low price elasticity of demand (perhaps zero over some price range) is insulin. Insulin is of such importance to some diabetics that if the price rises or falls, they do not change the quantity they buy.

If the percentage change in the quantity demanded equals the percentage change in the price, then the price elasticity equals 1 and the good is said to have a **unit elastic demand**. The demand in Fig. 4.3(b) is an example of a unit elastic demand.

Between the cases shown in Fig. 4.3(a) and Fig. 4.3(b) is the general case in which the percentage change in the quantity demanded is less than the percentage change in the price. In this case, the price elasticity of demand is between zero and 1 and the good is said to have an **inelastic demand**. Food and shelter are examples of goods with inelastic demand.

**FIGURE 4.3** Inelastic and Elastic Demand




**(a) Perfectly inelastic demand** **(b) Unit elastic demand** **(c) Perfectly elastic demand**

Each demand illustrated here has a constant elasticity. The demand curve in part (a) illustrates the demand for a good that has a zero elasticity of demand. The demand curve in part (b) illustrates the demand for a good with a unit elasticity of demand. And the demand curve in part (c) illustrates the demand for a good with an infinite elasticity of demand.

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If the quantity demanded changes by an infinitely large percentage in response to a tiny price change, then the price elasticity of demand is infinity and the good is said to have a **perfectly elastic demand**. Figure 4.3(c) shows a perfectly elastic demand. An example of a good that has a very high elasticity of demand (almost infinite) is a soft drink from two campus machines located side by side. If the two machines offer the same soft drinks for the same price, some people buy from one machine and some from the other. But if one machine's price is higher than the other's, by even a small amount, no one buys from the machine with the higher price. Drinks from the two machines are perfect substitutes. The demand for a good that has a perfect substitute is perfectly elastic.

Between the cases in Fig. 4.3(b) and Fig. 4.3(c) is the general case in which the percentage change in the quantity demanded exceeds the percentage change in price. In this case, the price elasticity of demand is greater than 1 and the good is said to have an **elastic demand**. Automobiles and furniture are examples of goods that have elastic demand.

## Elasticity Along a Linear Demand Curve

Elasticity and slope are not the same. A linear demand curve has a constant slope but a varying elasticity. Let's see why.

The demand curve in Fig. 4.4 is linear. A \$5 fall in the price brings an increase of 10 pizzas an hour no matter what the initial price and quantity.

Let's now calculate some elasticities along this demand curve.

At the midpoint of the demand curve, the price is \$12.50 and the quantity is 25 pizzas per hour. When the price falls from \$15 to \$10 a pizza the quantity demanded increases from 20 to 30 pizzas an hour and the average price and average quantity are at the midpoint of the demand curve. So

$$\text{Price elasticity of demand} = \frac{10/25}{5/12.25} = 1.$$

That is, at the midpoint of a linear demand curve, the price elasticity of demand is one.

At prices *above* the midpoint, demand is elastic. For example, when the price falls from \$25 to \$15 a pizza, the quantity demanded increases from zero to 20 pizzas an hour. The average price is \$20 a pizza, and the average quantity is 10 pizzas. So

$$\text{Price elasticity of demand} = \frac{\Delta Q/Q_{ave}}{\Delta P/P_{ave}} = \frac{20/10}{10/20} = 4.$$

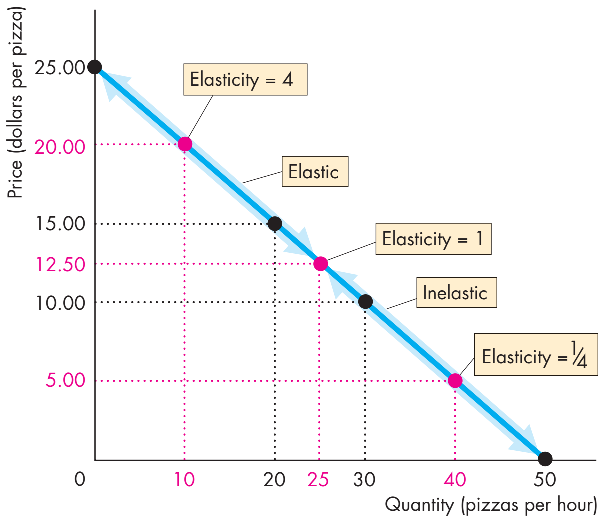
That is, the price elasticity of demand at an average price of \$20 a pizza is 4.

At prices *below* the midpoint, demand is inelastic. For example, when the price falls from \$10 a pizza to zero, the quantity demanded increases from 30 to 50 pizzas an hour. The average price is now \$5 and the average quantity is 40 pizzas an hour. So

$$\text{Price elasticity of demand} = \frac{20/40}{10/5} = 1/4.$$

That is, the price elasticity of demand at an average price of \$5 a pizza is 1/4.

**FIGURE 4.4** Elasticity Along a Linear Demand Curve




On a linear demand curve, demand is unit elastic at the midpoint (elasticity is 1), elastic above the midpoint, and inelastic below the midpoint.

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## Total Revenue and Elasticity

The **total revenue** from the sale of a good equals the price of the good multiplied by the quantity sold. When a price changes, total revenue also changes. But a cut in the price does not always decrease total revenue. The change in total revenue depends on the elasticity of demand in the following way:

- If demand is elastic, a 1 percent price cut increases the quantity sold by more than 1 percent and total revenue increases.
- If demand is inelastic, a 1 percent price cut increases the quantity sold by less than 1 percent and total revenue decreases.
- If demand is unit elastic, a 1 percent price cut increases the quantity sold by 1 percent and total revenue does not change.

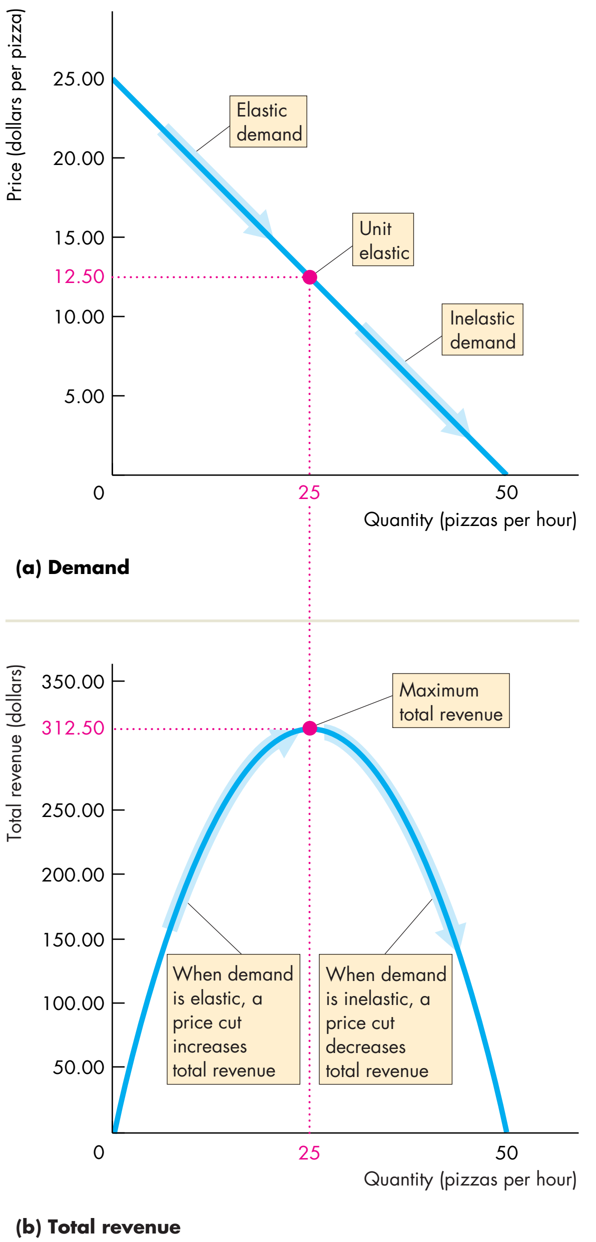
In Fig. 4.5(a), over the price range from $25 to $12.50, demand is elastic. Over the price range from $12.50 to zero, demand is inelastic. At a price of $12.50, demand is unit elastic.

Figure 4.5(b) shows total revenue. At a price of $25, the quantity sold is zero, so total revenue is zero. At a price of zero, the quantity demanded is 50 pizzas an hour and total revenue is again zero. A price cut in the elastic range brings an increase in total revenue—the percentage increase in the quantity demanded is greater than the percentage decrease in price. A price cut in the inelastic range brings a decrease in total revenue—the percentage increase in the quantity demanded is less than the percentage decrease in price. At unit elasticity, total revenue is at a maximum.

Figure 4.5 shows how we can use this relationship between elasticity and total revenue to estimate elasticity using the total revenue test. The **total revenue test** is a method of estimating the price elasticity of demand by observing the change in total revenue that results from a change in the price, when all other influences on the quantity sold remain the same.

- If a price cut increases total revenue, demand is elastic.
- If a price cut decreases total revenue, demand is inelastic.
- If a price cut leaves total revenue unchanged, demand is unit elastic.

**FIGURE 4.5** Elasticity and Total Revenue




When demand is elastic, in the price range from $25 to $12.50, a decrease in price (part a) brings an increase in total revenue (part b). When demand is inelastic, in the price range from $12.50 to zero, a decrease in price (part a) brings a decrease in total revenue (part b). When demand is unit elastic, at a price of $12.50 (part a), total revenue is at a maximum (part b).

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## Your Expenditure and Your Elasticity

When a price changes, the change in your expenditure on the good depends on *your* elasticity of demand.

- If your demand is elastic, a 1 percent price cut increases the quantity you buy by more than 1 percent and your expenditure on the item increases.
- If your demand is inelastic, a 1 percent price cut increases the quantity you buy by less than 1 percent and your expenditure on the item decreases.
- If your demand is unit elastic, a 1 percent price cut increases the quantity you buy by 1 percent and your expenditure on the item does not change.

So if you spend more on an item when its price falls, your demand for that item is elastic; if you spend the same amount, your demand is unit elastic; and if you spend less, your demand is inelastic.

## The Factors That Influence the Elasticity of Demand

The elasticity of demand for a good depends on

- The closeness of substitutes
- The proportion of income spent on the good
- The time elapsed since the price change

**Closeness of Substitutes** The closer the substitutes for a good or service, the more elastic is the demand for it. Oil from which we make gasoline has no close substitutes (imagine a steam-driven, coal-fueled car). So the demand for oil is inelastic. Plastics are close substitutes for metals, so the demand for metals is elastic.

The degree of substitutability depends on how narrowly (or broadly) we define a good. For example, a personal computer has no close substitutes, but a Dell PC is a close substitute for a Hewlett-Packard PC. So the elasticity of demand for personal computers is lower than the elasticity of demand for a Dell or a Hewlett-Packard.

In everyday language we call goods such as food and shelter *necessities* and goods such as exotic vacations *luxuries*. A necessity has poor substitutes and is crucial for our well-being. So a necessity generally has an inelastic demand. A luxury usually has many substitutes, one of which is not buying it. So a luxury generally has an elastic demand.

**Proportion of Income Spent on the Good** Other things remaining the same, the greater the proportion of income spent on a good, the more elastic (or less inelastic) is the demand for it.

## Economics in Action

### Elastic and Inelastic Demand

The real-world price elasticities of demand in the table range from 1.52 for metals, the item with the most elastic demand in the table, to 0.05 for oil, the item with the most inelastic demand in the table. The demand for food is also inelastic.

Oil and food, which have poor substitutes and inelastic demand, might be classified as necessities. Furniture and motor vehicles, which have good substitutes and elastic demand, might be classified as luxuries.

Price Elasticities of Demand

| Good or Service | Elasticity |
|---|---|
| **Elastic Demand** | |
| Metals | 1.52 |
| Electrical engineering products | 1.39 |
| Mechanical engineering products | 1.30 |
| Furniture | 1.26 |
| Motor vehicles | 1.14 |
| Instrument engineering products | 1.10 |
| Professional services | 1.09 |
| Transportation services | 1.03 |
| **Inelastic Demand** | |
| Gas, electricity, and water | 0.92 |
| Chemicals | 0.89 |
| Drinks | 0.78 |
| Clothing | 0.64 |
| Tobacco | 0.61 |
| Banking and insurance services | 0.56 |
| Housing services | 0.55 |
| Agricultural and fish products | 0.42 |
| Books, magazines, and newspapers | 0.34 |
| Food | 0.12 |
| Oil | 0.05 |

*Sources of data:* Ahsan Mansur and John Whalley, "Numerical Specification of Applied General Equilibrium Models: Estimation, Calibration, and Data," in *Applied General Equilibrium Analysis*, eds. Herbert E. Scarf and John B. Shoven (New York: Cambridge University Press, 1984), 109, and Henri Theil, Ching-Fan Chung, and James L. Seale, Jr., *Advances in Econometrics, Supplement I, 1989, International Evidence on Consumption Patterns* (Greenwich, Conn.: JAI Press Inc., 1989), and Geoffrey Heal, Columbia University, Web site.