Noah Berger/AP Images

▲ How expensive could gasoline get before you stop buying it?

CHAPTER 4

Elasticity

A Measure of Responsiveness

Imagine that the price of gasoline doubled tomorrow. Some drivers might cut back a little, and those in the market for new cars might opt for more fuel-efficient models. But people still need to get to work or to school, and switching to a more fuel-efficient car is expensive. So in the short run consumers would grudgingly continue to buy almost as much gasoline even after prices spike, and cross their fingers in the hope that prices will come back down soon.

On the other hand, what would happen if the price of books sold on Amazon were to suddenly double? It's likely even avid readers would buy fewer books from the website. Some would look for discounted books at places like Costco and Target; others might start shopping at local used bookstores; and some would simply check out books for free from their local library.

None of this is surprising. As we learned in Chapter 3, the law of demand suggests that when price decreases, quantity demanded increases. But just *how much* will quantity demanded change when price changes? Executives at Coca-Cola know that they'll sell less Coca-Cola if they raise the price—but how much less? And how much less Coca-Cola would they sell if alternatives like bottled water or iced tea suddenly became less expensive? Economics provides a way to measure market response to changes in variables such as price, income, and the price of alternatives. That measure, called *elasticity,* is the focus of this chapter.

Chapter Learning Targets

- Define the concept of price elasticity of demand.
- Demonstrate how price elasticity of demand is calculated.
- Recognize the links between price changes, the price elasticity of demand, and total revenue.
- Identify the concepts of cross-price elasticity and income elasticity.
- Explain the concept of price elasticity of supply and how to calculate it.

4.1 THE PRICE ELASTICITY OF DEMAND

The first three chapters looked at how people respond to changing incentives; this chapter looks at *how much* they respond. **Elasticity** is a measure of responsiveness to a change in market conditions. Economists use it to determine the degree to which one economic variable, such as quantity, responds to changes in other economic variables. There are a variety of measures of elasticity. We begin by analyzing how a price change impacts quantity demanded.

How Much Quantity Demanded Changes When Price Changes

At its heart, elasticity is a measure of *responsiveness,* of how much quantity will be impacted by economic events such as price changes. As noted earlier, consumers are generally not very responsive to changes in the prices of gasoline—at least in the short run. Demand for some items—such as medicine, cigarettes, coffee, and air travel for business—tends to change only slightly in response to fluctuations in price. These products are said to be price inelastic with respect to demand. Demand for other items, like Coca-Cola, automobiles, or fast food, is elastic—quantity demanded tends to be relatively more responsive to changes in price.

The **price elasticity of demand (E_d)** is a measure of how responsive quantity demanded is to price changes; it equals the percentage change in quantity demanded divided by the percentage change in price. That is,

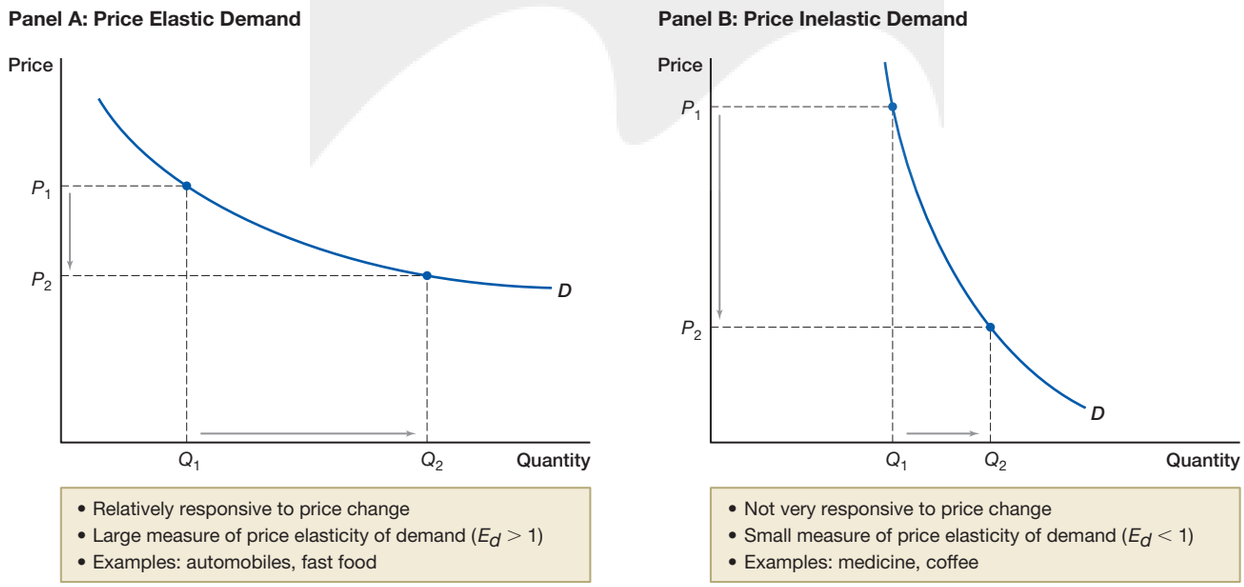
elasticity A measure of responsiveness to a change in market conditions.

price elasticity of demand (E_d) A measure of how responsive quantity demanded is to price changes; it equals the percentage change in quantity demanded divided by the percentage change in price.

$$E_d = \frac{\text{Percentage change in } Q_d}{\text{Percentage change in } P}$$

We'll get into the mathematics used to estimate the price elasticity of demand (E_d) later in this chapter. For now, understand that the larger E_d is (in absolute value), the more responsive quantity demanded is to a given price change. To begin, consider the two demand curves in Exhibit 1. Both curves are downward-sloping, which is consistent with the law of demand. Yet, the impact of a given price change in Panel A is considerably different than the impact of the same price change in Panel B. There are very different price elasticities of demand in the two curves.

EXHIBIT 1 Elastic and Inelastic Demand Curves



Panel A shows a price elastic demand curve. Quantity demanded is very responsive to price changes. The price elasticity of demand is greater than 1. Panel B shows a price inelastic demand curve. Quantity demanded is not very responsive to price changes. The price elasticity of demand is less than 1.

The demand curve in Panel A is relatively responsive, or *price elastic*. Quantity demanded is very responsive to a price change, moving by a larger percentage than price. Its measure of responsiveness E_d is greater than 1 because the percentage change in quantity is greater than the percentage change in price. The demand for luxury goods and a *specific brand* of a good tends to be price elastic as consumers respond to price increases by foregoing consumption or switching brands.

When compared to the demand curve in Panel A, the demand curve in Panel B is relatively unresponsive to price changes. This means the demand curve in Panel B is *price inelastic*. Quantity demanded is not very responsive to a price change, with quantity moving by a smaller percentage than price. Its measure of responsiveness E_d is less than 1 because the percentage change in quantity is less than the percentage change in price. For example, the demand for gasoline (when all stations raise their prices) and life-saving medicine tends to be price inelastic.

Factors That Influence Price Elasticity of Demand

A number of factors influence the price elasticity of demand. Let's consider a few of them, and see how basic economic theory can help us to understand why the price elasticity of demand varies so much from one product to the next.

Availability of Substitutes In general, demand for products with a lot of substitutes is price elastic: If peaches become 10% more expensive, consumers will switch to other fruits. The demand for Chevrolets and Rice Krispies is highly elastic. Consumers can easily switch to substitute products (such as Fords or Kellogg's Corn Flakes). Likewise, if one gas station charges 10 cents more per gallon than a nearby competitor, the high-priced station will likely experience sharply lower sales, *ceteris paribus.*

In contrast, when few substitutes are available, consumers are less responsive to price changes and the price elasticity of demand is lower (more inelastic). Here, we are assuming that *all* gasoline stations change their prices, not just a specific brand or station. That's why demand for gasoline as a whole is relatively price inelastic: Most consumers won't immediately stop using gas if the price goes up across all brands and at all gas stations.

Definition of the Market As you may have noticed, how a market is defined will impact how responsive consumers are to price changes. There is a big difference in the price elasticity of a broad category like "food" and that of a single item, like peaches, Coca-Cola, or potato chips. The demand for food, in general, is quite price inelastic—most of us would be hard pressed to identify substitutes (if you don't consume food, what would you eat?). But the demand for specific foods is much more price elastic. If the price of peaches, Coca-Cola, or potato chips increases, customers will opt for apples, iced tea, or pretzels. Branded potato chips, like Lay's or Pringles, have an even narrower market than "chips" in general, so their price elasticity of demand will be higher. Likewise, the price elasticity of demand will be higher for Coca-Cola than for all carbonated beverages. The more narrowly a product is defined, the more substitutes are likely to be available—and the more price elastic demand will be.

Time to Adjust We've discussed how gasoline is price inelastic in the short run, but as we noted in Chapter 1, economic outcomes frequently depend on the time frame involved. That's because when consumers have

Richard Levine/Alamy

▼ The availability of substitutes makes demand for specific brands highly price elastic.

more time to adjust to price changes, they can be more responsive to any price change. As a result, the price elasticity of demand is often higher in the long run than in the short run. For example, if gas prices spike, a commuter who drives a gas-guzzling SUV will likely continue to fill up for a while, but if the price of gas remains high for several weeks, he or she might start to look at alternative modes of transportation, such as carpooling or public transportation. In the long run, the driver might even consider switching to a more efficient or an electric vehicle.

Share of Budget If rents in your town suddenly doubled, chances are you'd start looking for a smaller apartment. But what would you do if the price of milk doubled? Or salt? The percentage change in price is the same in all three cases, and all three items are basic necessities. But the price increase for rent will have a much larger impact on your overall budget: Spending twice as much on rent will likely cost you thousands of additional dollars each year, while spending twice on a carton of milk will only cost you a few more dollars per week, and salt will only cost you a few more dollars per year, even at twice the current price. Demand for more expensive items tends to be more price elastic because they take up a larger share of consumer budgets: This puts more pressure on consumers to cut back and thus they are much more responsive.

Necessities, Luxuries, and Addictive Goods Consumers tend to be less responsive to the price changes of items they deem *necessities* than those they consider luxuries. In other words, changes in the price of necessities tend to have a fairly small impact on the quantity demanded. Products like emergency health-care services, business travel, groceries, and addictive items like coffee, cigarettes, beer, and narcotics are price inelastic, indicating that many consumers consider these products to be necessities, and will thus not reduce their consumption very much when prices rise. Demand for *addictive goods* can be very price inelastic. Demand for *luxuries* like fine restaurant meals, vacations, spa treatment services, and designer clothing, on the other hand, tends to be relatively price elastic: When the price of such a product rises, consumers may choose a cheaper option or simply go without it.

Advertising and Brand Loyalty Most non-economists are aware that businesses advertise to increase demand. But advertisers have an additional motive—to lower the price elasticity of demand for their product. Brands like Nike and Ralph Lauren spend huge amounts of money in advertising, in hopes of convincing consumers that other brands are not good substitutes. If they are successful, demand for their product will become less price elastic (more price inelastic).

4.2 MEASURING THE PRICE ELASTICITY OF DEMAND

We've seen that the price elasticity of demand is a measure of how responsive the quantity demanded is to price changes, other things equal. We've also examined factors that determine the price elasticity of demand. We will now examine how we compute the price elasticity of demand and why it is important to never reason from a price change when doing so. We will also look at real-world estimates of the price elasticity of demand.

Computing the Price Elasticity of Demand (E_d)

Recall that the price elasticity of demand is equal to the percentage change in quantity demanded divided by the percentage change in price. Earlier, this was shown as

$$E_d = \frac{\text{Percentage change in } Q_d}{\text{Percentage change in } P}$$

This equation can also be expressed as

$$E_d = \frac{\%\Delta Q_d}{\%\Delta P}$$

where the Greek letter Δ (delta) means change, $\%\Delta Q_d$ thus means percentage change in quantity demanded, while $\%\Delta P$ means percentage change in price.

How does one calculate percentage change (%Δ)? The *standard* way to calculate a percent change in price is the change in price over the initial price, expressed as a percentage. Such calculations are familiar to most consumers: When a North Face fleece jacket is marked down from $100 to $75, shoppers will say the jacket is 25% off. Likewise, when a large pizza once priced at $30 now costs $20, you can say the pizza is one third, or roughly 33%, off. That is,

$$\%\Delta P = \frac{\text{Change in price}}{\text{Initial price}} = \frac{\$20 - \$30}{\$30} = \frac{-\$10}{\$30} = -33.3\%$$

Unfortunately, this standard formula for calculating percentage change is problematic in that it depends on the direction of the change. For example, if the price of the large pizza rises by the same amount—that is, from $20 to $30—the percentage change in price is *not* 33.3%. Rather, it is 50%.

$$\%\Delta P = \frac{\text{Change in price}}{\text{Initial price}} = \frac{\$10}{\$20} = 50\%$$

Since the direction of the price change impacts the estimate of percentage change using the standard formula, it also affects estimates of price elasticity of demand. That is to say, using the standard formula for calculating percentage change would result in different values for the price elasticity of demand for price increases and decreases. To avoid this ambiguity, economists use an alternative measure of percentage change.

Using the Midpoint Method to Estimate the Price Elasticity of Demand To overcome ambiguity related to the direction of the price change, economists use what is known as the *midpoint method* to estimate percentage changes when calculating elasticities.

A midpoint is simply the *average* of the two end points: Rather than divide by $20 or $30 in the above pizza example (the two initial prices), economists divide by $25, the midpoint (or average) of $20 and $30. Using the midpoint method to calculate percentage change in price, we get

$$\%\Delta P_{\text{midpoint}} = \frac{\text{Change in price}}{\text{Midpoint price}} = \frac{10}{(20 + 30)/2} = \frac{10}{25} = 40\%$$

Using the midpoint formula ensures that we arrive at a single estimate of the price elasticity of demand for both price increases and price decreases. Remember, percentage change using the midpoint method is simply change over the average value. The basic idea is still the same.

$$E_d = \frac{\%\Delta Q_d}{\%\Delta P} = \frac{\dfrac{\Delta Q}{\text{Midpoint } Q}}{\dfrac{\Delta P}{\text{Midpoint } P}} = \frac{\left(\dfrac{\Delta Q}{(Q_1 + Q_2)/2}\right)}{\left(\dfrac{\Delta P}{(P_1 + P_2)/2}\right)}$$

Using the midpoint method, price elasticity of demand is the change in Q_d over average (midpoint) quantity, divided by change in P over the average (midpoint) price.

Expressions of Price Elasticity of Demand The price elasticity of demand is technically a *negative* number, as demand curves have a negative slope due to the law of demand (i.e., $E_d = < 0$). However, business analysts and economists often express the price elasticity of demand values as a *positive* number. To keep things simple, price elasticity is

frequently expressed in terms of *absolute value* (i.e., how far it is from zero in either direction). The law of demand is so widely recognized that it's understood that a demand price elasticity of 0.75 is actually shorthand for −0.75. In this book, we use the shorthand technique and refer to price elasticity of demand estimates in terms of absolute value. Keep in mind that in other places, you may occasionally come across an expression of demand elasticity that includes a negative sign.

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While price elasticity of demand estimates are almost universally *negative*, they are frequently expressed as a *positive* number. Thus, $E_d = 0.75$ is actually shorthand for negative 0.75.

Estimating Price Elasticity of Demand Suppose Mario is the only pizza seller in town. In addition, suppose that if the price of Mario's large pizza is $20, the quantity of large pizzas demanded is 1,500, and that only 900 are demanded if the price of a large pizza increases to $30:

Price of a Large Pizza

Price	Quantity
$20	1,500
$30	900

In this case, the price of elasticity of demand for Mario's pizza is

$$E_d = \frac{\%\Delta Q}{\%\Delta P} = \frac{\dfrac{\Delta Q}{\text{Midpoint } Q}}{\dfrac{\Delta P}{\text{Midpoint } P}} = \frac{\left(\dfrac{600}{1{,}200}\right)}{\left(\dfrac{10}{25}\right)} = \frac{0.50}{0.40} = 1.25$$

In estimating the price elasticity of demand for pizza, we first estimate the percentage change in quantity. This is the change in quantity (an absolute value of 600) over the midpoint quantity (1,200), which equals (1,500 + 900)/2, which equals 0.50 (or 50%). Next, we calculate the percentage change in price, which is the change in price (10) over the midpoint price (25). This equals 0.40 (or 40%). Finally, we divide the percentage change in quantity (50%) by the percentage change in price (40%), which leads to the result that the $E_d = 1.25$.

Alternatively, consider the price elasticity of demand for toppings:

Price of Toppings

Price	Quantity
$2	1,100
$3	900

$$E_d = \frac{\%\Delta Q}{\%\Delta P} = \frac{\left(\dfrac{\Delta Q}{\text{Midpoint } Q}\right)}{\left(\dfrac{\Delta P}{\text{Midpoint } P}\right)} = \frac{\left(\dfrac{200}{1{,}000}\right)}{\left(\dfrac{1}{2.50}\right)} = \frac{0.20}{0.40} = 0.5$$

Once again, the price elasticity of demand is estimated as the percentage change in quantity over the percentage change in price. Here, the absolute value of the percentage change in quantity is 0.20 (or 20%) and the percentage change in price is 0.40 (40%). The elasticity of demand is 0.20 over 0.40, which leads to the result that $E_d = 0.50$.

What Price Elasticity of Demand (E_d) Means What does a price elasticity of demand equal to 1.25 mean? For starters, it means the price elasticity of demand for a large pizza is *elastic,* as it is greater than 1: Quantity demanded changes by relatively more than price. It also means that consumers are somewhat flexible; they can shift to alternative products if the price rises. The higher the price elasticity of demand, the more price elastic a good is. A price elasticity of 1.25 means if price changes by 1%, quantity will change by 1.25%.

Alternatively, the price elasticity of demand for toppings is 0.50. Individuals who want specific toppings on their pizza—pepperoni, onions, or mushrooms—are often not very responsive to price changes in these toppings. You would probably notice if your local pizzeria increased the price of its pie, but you might pay little attention to changes in the price of toppings. That is to say, the price elasticity of demand of toppings tends to be *inelastic,* with a price elasticity less than 1, meaning the percentage change in quantity (in the numerator) is less than the percentage change in price (in the denominator). In this example, toppings on pizzas are price inelastic, with each 1% increase in price reducing quantity demanded by 0.5%. As a result, if Mario raises the price of toppings by 10%, he can expect topping sales to decline by only 5%. Likewise, in the auto industry, consumers are very sensitive to the base price of cars, but often pay less attention to the price of fancy options like alloy wheels.

Thomas Padilla/Newscom

A better burger, with a slice of inelastic cheese.

BUSINESS BRIEF Five Guys: How Much Would You Pay for a Slice of Cheese?

The fast-food chain Five Guys dominates what is known as the "better burger" category of casual dining. In 2018, it had over 1,000 locations and was one of the fastest-growing fast-food restaurant in the United States.* Prices at Five Guys are, on average, higher than those found at other fast-food burger places, in part due its high-quality ingredients.

Management at Five Guys appears to have considered price elasticities when designing its menu. The price of its "Little Hamburger" jumps from $4.99 to $5.69 when cheese is added, and to $6.69 when both cheese and bacon are added. Similarly, the price of its hot dogs increases from $4.69 to $5.39 when customers add cheese.† That's 70 cents for 1 slice of cheese! Remember, items that are a small share of one's budget tend to be less responsive to price changes—that is to say, they tend to be price inelastic. The demand for that extra slice of cheese on a burger is probably price inelastic. Savvy business owners can—and do—capitalize on these elasticities.

*Monte Burke, "Five Guys Burgers: America's Fastest Growing Restaurant Chain," *Forbes*, July 18, 2012, https://www.forbes.com/forbes/2012/0806/restaurant-chefs-12-five-guys-jerry-murrell-all-in-the-family.html.

†"Five Guys Prices," *FastFoodMenuPrices.com*, 2018, http://www.fastfoodmenuprices.com/five-guys-prices/.

Real-World Estimates of Price Elasticity of Demand

The law of demand tells us that price increases reduce quantity demanded, while the concept of elasticity tells us by *how much*. In this section, we look at real-world estimates of the price elasticity of demand for various products and discuss these values in the context of factors that influence price elasticity of demand.

Exhibit 2 shows real-world price elasticity of demand estimates for various products. In these examples, you will notice some patterns consistent with factors that determine the price elasticity of demand. First, due to the *availability of substitutes,* demand for a specific seller like Coca-Cola, Kellogg's, Walmart, Amazon, or Chevrolet is generally more price elastic than for broad product categories like food, cars, or retailers. Due to having more *time to adjust,* demand for both gasoline and automobiles is less price elastic in the short run than in the long run. Due to being a small *share of a budget,* inexpensive items such as salt tend to have less price elastic demand than expensive goods like foreign air travel and automobiles. Food is a broad *definition of a market* and has a less price elastic demand than Coca-Cola and Rice Krispies. Demand for *luxury* goods like foreign travel is price elastic, while demand for *necessities* like food and some health-care services is price inelastic. Demand for *addictive goods* and *necessities* such as cigarettes, coffee, alcohol, and narcotics is typically price inelastic.

EXHIBIT 2 Real-World Estimates of Price Elasticity of Demand

Inelastic Goods ($E_d < 1$)	Price Elasticity of Demand	Elastic Goods ($E_d > 1$)	Price Elasticity of Demand
Health Care (appendectomy)	<0.1	Air Travel (general)	1.1
Health Care (arm cast)	< 0.1	Breakfast Cereal (all)	1.3
Salt	0.1	Fast Food	1.7
Gasoline (short-run)	0.2–0.3	Retail Products (Walmart)	1.9
Coffee	0.3	Health Care (psychologist visit)	2.1
Beer	0.3	Automobiles (all, long-run)	2.2
Gasoline (long-run)	0.6–0.9	Kellogg's Rice Krispies	2.2
Illicit Drugs (cocaine)	0.3	Online Products (at Amazon)	3.2
Cigarettes	0.4	Automobiles (Chevrolet)	1.8–2.1
Air Travel (business)	0.5	Air Travel (long-run)	2.1
Food	0.6	Foreign Travel (long-run)	4.1
Lottery Ticket (large jackpot)	0.8	Coca-Cola	4.1

Estimates of the price elasticity of demand for a variety of products.
Data compiled by the authors; see chapter notes (p. R-1) for list sources.

Ranges of Price Elasticity of Demand and Extreme Cases

The price elasticity of demand can range from zero to infinity. The larger the value of the price elasticity of demand, the more elastic the item is. These values are summarized in Exhibit 3. Most goods are either price elastic or price inelastic. On occasion, the price elasticity of demand is categorized as *perfectly inelastic* ($E_d = 0$), *unit elastic* ($E_d = 1$), or *perfectly elastic* ($E_d =$ infinity). We discuss each of these possibilities in turn.

Perfectly Inelastic Demand ($E_d = 0$) Panel A of Exhibit 3 shows a *perfectly inelastic* demand curve. It is a vertical line, meaning the quantity demanded never changes. In this case, the $\%\Delta Q$ is zero.

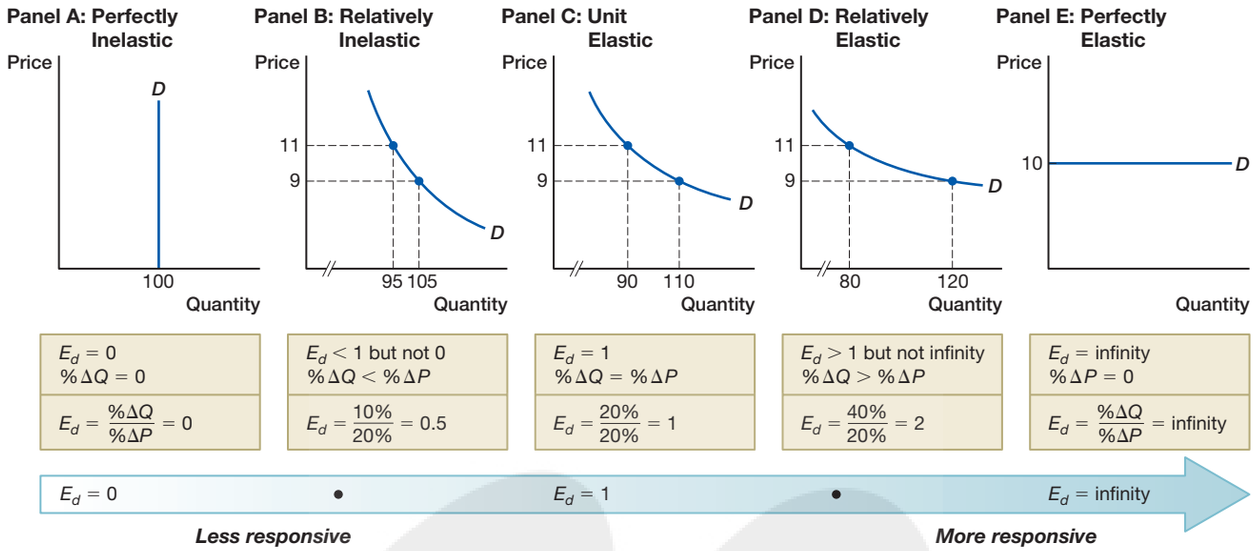
While this example is theoretically possible, it is very unlikely. One example that people often cite is medicine needed to survive—a consumer, it is assumed, will demand the same quantity of a life-saving medication, regardless of increases (or decreases) in price. However, even life-saving medicine does not have a *perfectly* inelastic demand: At unaffordable prices, quantity demanded falls and the price elasticity of demand is no longer zero.

Inelastic Demand ($E_d < 1$) Panel B demonstrates a relatively price inelastic demand curve. In most cases, a change in price will change quantity demanded. The question is by how much. When demand is price inelastic, the percentage change in quantity demanded is smaller than the percentage change in price. Consumers are not very responsive to price changes. Since $E_d = \%\Delta Q/\%\Delta P$ and the numerator is smaller than the denominator, E_d must be less than 1 when demand is inelastic. As we've discussed, the demand for gasoline and medicine tends to be price inelastic.

Unit Elastic ($E_d = 1$) Panel C shows an interesting case occurs when the price elasticity of demand equals 1. In this instance, the percentage change in quantity equals the percentage change in price. This is referred to as unit elastic demand. In the E_d equation, the numerator ($\%\Delta Q$) must equal the denominator ($\%\Delta P$).

Elastic Demand ($E_d > 1$) Panel D shows the case where demand is relatively price elastic. Here, the percentage change in quantity demanded is greater than the

EXHIBIT 3 Graphical Summary of the Price Elasticity of Demand



Estimates of the price elasticity of demand can range from zero (perfectly inelastic) to infinity (perfectly elastic).

percentage change in price, and the price elasticity of demand is greater than 1. In this case, consumers will respond to a price increase by sharply cutting back on purchases. As we've learned, the demand for a specific brand of gasoline, food item, or automobile tends to be price elastic.

Perfectly Elastic Demand (E_d = Infinity) Panel E also shows a perfectly elastic demand curve. It is a horizontal line. The quantity demanded for such an item falls to zero if the price rises by even 1 cent. This is approximately the demand curve that faces small firms in perfect competition. Consider a small egg farmer that produces between 100 and 200 dozen eggs a month. If monthly egg production is 625,000,000 (as it was in the United States in October 2016), the small farmer's impact on market price is likely very close to zero. This farmer takes the market price as given and simply sells as many as she chooses to produce at the current market price. The demand for an individual farmer's eggs is (almost) infinitely elastic. If she raised her price, quantity demand would fall to almost zero, as many other producers will be willing to sell at a lower price.

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When demand is price elastic, it means the price elasticity of demand is greater than 1, thus the percentage change in quantity is greater than the percentage change in price. When demand is price inelastic, it means the price elasticity of demand is less than 1.

BUSINESS BRIEF Is Demand for Life-Saving AIDS Drug Perfectly Price Inelastic?

Perfectly inelastic demand is rare and may not even apply to life-saving medicines. For example, the first successful treatments for AIDs were developed in the late 1990s. These drugs were very expensive and thus out of reach for many AIDS patients—particularly those in the developing world. In 2001, British pharmaceutical company GlaxoSmithKline reduced the price of its AIDS drugs in the 63 poorest countries of the world (by varying amounts) in response to competitive pressure from generic "copycats" in countries where such substitutes were legally sold. Subsequently, sales tripled from 2 million people treated to 6 million.* This increase in

sales indicates that even the demand for life-saving drugs is not *perfectly* inelastic: The lower price increased the quantity demanded.

*Sarah Boseley and Tim Radford, "Glaxo Cuts Price of AIDS Drugs in Poor Countries," *The Guardian,* April 28, 2003, http://www.theguardian.com/uk/2003/apr/28/sciencenews.globalisation.

>Measuring Elasticity: Never Reason from a Price Change

Businesses are very concerned with how supply changes might impact the price of goods that they sell, and how this impacts the quantity sold. To answer these questions, businesses need to know the price elasticity of demand.

You might think it would be easy to calculate price elasticity of demand. Simply see what happens to sales when the price changes. But remember: Economists should *never reason from a price change*. If the price of a good rises, the quantity purchased could go up or down, depending on whether the price increase was caused by lower supply or higher demand.

Elasticity measures responsiveness to price changes along a *given* demand curve. But what if price changes *because demand has shifted*? When calculating demand elasticity, economists seek to avoid cases where the price changed because the demand curve itself shifted. For this reason, economists look for price changes caused by shifts in supply. The goal is to find two points along a given demand curve, before and after supply shifts.

For example, the government raising taxes on cigarettes paid by sellers will reduce supply and result in a shift along the demand curve. The change in consumer quantity demanded after the tax increase will help us determine the price elasticity of demand for cigarettes. For instance, if a 10% price rise caused by higher taxes leads to a 5% drop in cigarette sales, then the price elasticity of demand would be 0.5.

Alternatively, you could look at the price and quantity of coffee before and after a crop failure that caused the supply of coffee to decrease. Neither crop failures nor tax paid by sellers increases are likely to change the public's underlying demand for the product; rather, price changes along a given demand curve. Those events allow you to see how consumers respond to price change holding the demand curve constant.

Today, researchers use *econometrics* (advanced statistical models) that attempt to control for other real-world changes, allowing economists to focus on the key relationships between price and quantity demanded.

4.3 HOW A PRICE CHANGE AFFECTS UNIT SALES AND SALES REVENUE

Once a business has developed a good estimate of the price elasticity of demand for its product, it is a straightforward mathematical calculation to use this number in estimating the impact of price changes on sales. Price changes can affect what businesses refer to as *unit sales*—or more commonly what economists refer to as quantity demanded. Price changes can also affect *sales revenue,* the amount of money received by selling these units. Each of these measures of sales is significantly impacted by the price change and the price elasticity of demand for the firm's product.

How a Price Change Affects Quantity Demanded

In deciding whether to change prices, businesses often consider the impact of price changes on quantity demanded (unit sales). Recall the formula to estimate price elasticity of demand:

$$E_d = \frac{\%\Delta Q_d}{\%\Delta P}$$

There are three variables (E_d, $\%\Delta P$, and $\%\Delta Q$). If two of these variables are known, it is simple to find the third. Let's assume that the price elasticity of demand for Mario's pizzas has previously been estimated and Mario wants to know how a price increase will affect his sales. In that case, the above equation can be rewritten as

$$\%\Delta Q_d = E_d \times \%\Delta P$$

For example, if Mario knows the price elasticity of demand for his pizza is 2, and he is considering raising prices by 5%, what impact will that increase have on his sales? They will decline by 10%. Once again, remember that a negative relationship exists between price and quantity demanded.

How a Price Change Affects Total Revenue

In deciding whether to change prices, businesses also consider the impact of price changes on sales revenue or what economists refer to as total revenue or simply revenue. **Total revenue** (revenue) is the money a business receives from the sale of a product, calculated as the price of the good times the quantity sold. That is,

$$\text{Total revenue } (TR) = \text{Price} \times \text{Quantity}$$

For example, if Mario can sell 10 pizzas for $15, his total revenue will be $150. Since demand curves are downward-sloping, the impact of price increases on total revenue is uncertain because higher prices lower the quantity demanded. Thus, if price increases by 5% and quantity falls by 5%, total revenue will change very little. In general, higher prices increase total revenue, while the reduced quantity decreases total revenue. A trade-off occurs. Because P and Q move in opposite directions, the net effect on total revenue is unclear. It depends on the relative size of the percentage change in quantity and the percentage change in price:

$$? \text{ Total revenue } (TR) = \uparrow \text{Price} \times \downarrow \text{Quantity}$$

Can you have more total revenue with fewer unit sales? Earlier, we considered the case of Mario selling 1,100 pizza toppings for $2 each. In that case, his total revenue for selling toppings would be $2,200 ($2 × 1,100). We also noted that Mario could sell 900 toppings for $3 each. In that case, his total revenue for selling toppings would be $2,700 ($3 × 900). Mario receives more revenue when he sells fewer toppings! The relationship results from the fact that the price elasticity of demand for toppings is inelastic. As you will soon discover, this is not the case when the price elasticity of demand is elastic, as is the case for e-books.

Think & Speak Like an Economist

Businesses commonly use terms such as *unit sales* and *sales revenue*. The equivalent terms in economics are *quantity demanded* and *total revenue*. When economists use the term *revenue*, they typically are referring to *total revenue*.

BUSINESS BRIEF Amazon Defends Its e-Book Pricing Strategy

Books—and particularly e-books sold on Amazon.com—compete in markets where many substitutes are available: Readers can opt to purchase print books sold on Amazon and elsewhere; they can buy used books; or they can borrow print books or e-books for free from their local library. So, it should not surprise you that books, and e-books especially, have highly price elastic demand. In 2014, Amazon became embroiled in a lawsuit with the Hachette Book Group: Hachette argued that publishers should be able to determine the price of e-books sold on Amazon. The online giant asserted that a retailer like itself should be able to offer discounts. In defending its strategy, Amazon acknowledged the high price elasticity of e-books. Specifically, Amazon's data showed that the firm could sell 1.74 times as many copies of a book if it lowered the price from $14.99 to $9.99:

> [E]-books are highly price-elastic. . . . [W]e've quantified the price elasticity of e-books. . . . If customers would buy 100,000 copies of a particular e-book at $14.99, then customers would buy 174,000 copies of that same e-book at $9.99. Total revenue at $14.99 would be $1,499,000. Total revenue at $9.99 is $1,738,000.*

total revenue The money a business receives from the sale of a product, calculated as the price of the good times the quantity sold; also called *revenue*.

The two sides eventually came to an agreement that allowed publishers to still determine the prices for their titles. In return, Amazon was granted the right to provide Hachette with incentives to keep their prices low in order to take advantage of the fact that when demand is elastic, lower prices actually lead to higher total revenue.[†]

*"Update Regarding Amazon/Hachette Business Interruption," *Amazon.com* Kindle Forum, July 29, 2014.

†"Frozen Conflict," *The Economist*, November 14, 2014, http://www.economist.com/news/business-and-finance/21632802-deal-between-two-firms-unlikely-end-dispute-over-prices-and-profits-e-books-frozen.

Price Increase with Inelastic Demand Increases Total Revenue Consider the demand curve for inelastic goods such as pizza toppings, health care, certain pharmaceuticals, gasoline, or coffee. Compare the previous equation with the one below, in which differently sized arrows are used to reflect the magnitude of the changes (with a small arrow [“↓”] indicating a small change, and a large arrow [“↑”] indicating a bigger change).

When the price elasticity of demand is less than 1 (inelastic):

$$E_d < 1 \text{ (inelastic) if } \frac{\downarrow \%\Delta Q_d}{\uparrow \%\Delta P}$$

$$\uparrow \text{Total revenue } (TR) = \uparrow \text{Price} \times \downarrow \text{Quantity}$$

Remember that when demand for an item is price inelastic, the percentage change in quantity is smaller than the percentage change in price ($\%\Delta Q < \%\Delta P$). When a business sells a product for which its own brand is price inelastic, it can raise prices by a significant amount without much impact on quantity demanded. In that case, total revenue will rise. Similarly, a really popular restaurant or Broadway play can increase its prices and also increase revenue. Lowering prices has the opposite effect.

Price Increase with Elastic Demand Decreases Total Revenue If Mario’s pizzeria is located in a town with numerous restaurants, he will likely face demand for his pizza that is price elastic. This means the percentage change in quantity is greater than the percentage change in price ($\%\Delta Q > \%\Delta P$). Consider a neighborhood with four pizza shops, one with a price $1.00 higher than the others. What happens to sales at the pizza shop with a slightly higher price, if other things are held equal? Are sales a lot lower, or just a little bit lower? Since the product demand at any single pizza shop is typically price elastic, the quantity sold at the restaurant that raises prices will be a lot lower.

When the price elasticity of demand is greater than 1 (elastic),

$$E_d > 1 \text{ (elastic) if } \frac{\downarrow \%\Delta Q_d}{\uparrow \%\Delta P}$$

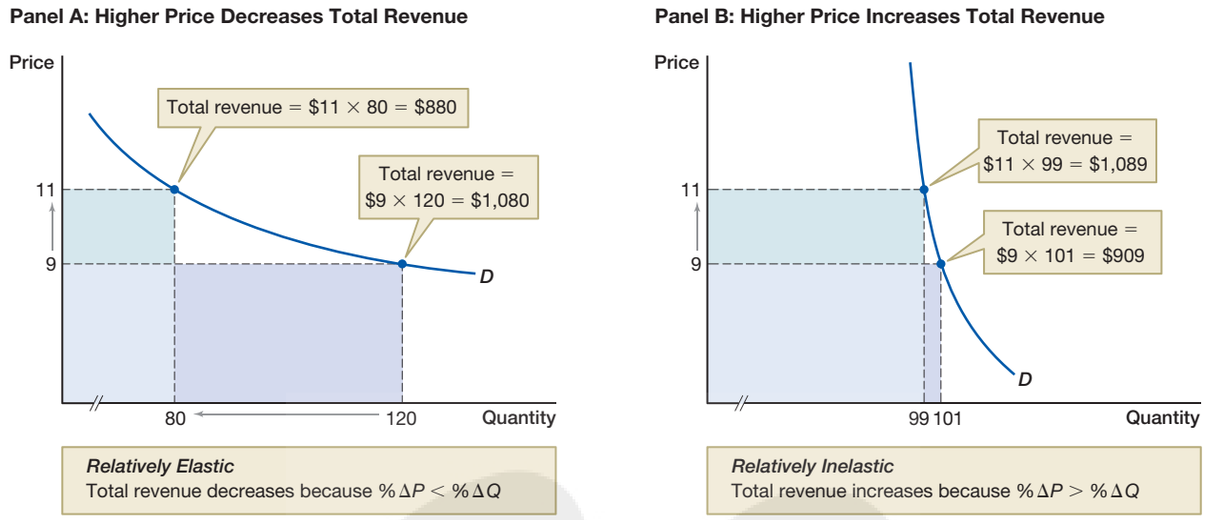
$$\downarrow \text{Total revenue } (TR) = \uparrow \text{Price} \times \downarrow \text{Quantity}$$

This means that increasing the price of elastic goods such as pizza will result in lower total revenue. Conversely, lowering the price will actually increase total revenue, as Amazon discovered in the case of e-books.

Exhibit 4 demonstrates the impact of a price increase on total revenue when demand is price elastic and price inelastic. In both cases, price increases by 20% using the midpoint method. When demand is price elastic, quantity changes by 40% and E_d is 2.0 (= 40%/20%). As a consequence, total revenue declines from $1,080 to $880. In contrast, when demand is price inelastic, quantity changes by 2% and E_d is 0.1 (= 2%/20%). As a consequence, total revenue increases from $909 to $1,089.

In summary, firms must consider the price elasticity of demand for their specific product when determining the impact of a price change on total revenue.

EXHIBIT 4 Price Increases, Total Revenue, and Price Elasticity of Demand



In both panels, price increases by 20% using the midpoint method. In Panel A, demand is price elastic, quantity decreases by 40%, and total revenue decreases. In Panel B, demand is price inelastic, quantity decreases by 2%, and total revenue increases.

In general, *price increases*:

- Increase total revenue when the firm is facing demand that is price inelastic
- Decrease total revenue when the firm is facing demand that is price elastic

In contrast, *price decreases*:

- Decrease total revenue when the firm is facing demand that is price inelastic
- Increase total revenue when the firm is facing demand that is price elastic

Use Firm-Specific Price Elasticity of Demand Estimates Remember that even though demand for a product category might be price inelastic, the demand for an individual firm selling that good is often price elastic. For instance, a rise in the overall market price of gasoline will likely cause only a small reduction in quantity demanded by consumers (in Exhibit 2, $E_d = 0.2 - 0.3$). Revenue to the industry would rise. But if only *one* gas station raises its price, some consumers will switch to other sellers, often one just down the street. Revenue to that individual seller will thus fall.

Likewise, the demand for food is, in general, price inelastic—but if only one pizza seller were to increase its price, the quantity sold by that seller will decline relatively sharply. In pricing its e-books, Amazon had to consider the price elasticity of demand for its specific product, *not* the price elasticity of demand for all books, or even all e-books. In business, it's very important to distinguish between the price elasticity of demand for the overall market and the individual firm's price elasticity of demand, which is generally much more elastic.

Price Elasticity and Total Revenue Along a Linear Demand Curve

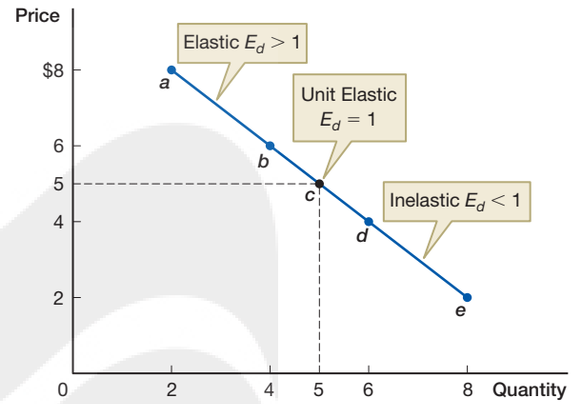
In general, the price elasticity of demand changes as one moves along the demand curve. In most cases, higher prices lead to a higher elasticity of demand. Indeed, such is always true for linear (straight) demand curves drawn as shown in Exhibit 5. This is, in part, due to the mathematics of a linear demand curve (the percentage change from $2 to $4 is larger than from $6 to $8) and, in part, due to the fact that

EXHIBIT 5 Elasticity and Total Revenue Along a Linear Demand Curve

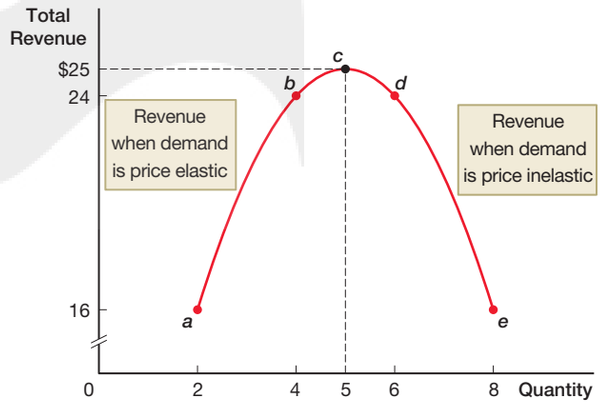
Panel A: Total Revenue at Various Prices

Points	Price	Quantity	Total Revenue
a	$8	2	$16
b	6	4	24
c	**5**	**5**	**25**
d	4	6	24
e	2	8	16

Panel B: Price Elasticty Varies Along Demand Curve



Panel C: Total Revenue Corresponds to Points on Demand Curve



Panel A shows total revenue at various price points and various estimates of the price elasticity of demand. Notice that demand tends to be more price elastic at higher prices and price inelastic at lower prices. Raising the price from $2 to $4 increases total revenue as demand is price inelastic, while raising the price from $6 to $8 decreases total revenue as demand is price elastic. Panel B displays the corresponding linear demand curve and Panel C the corresponding total revenue curve. Total revenue is maximized where the demand curve is unit elastic. At a price of $5, 5 units are sold and total revenue is $25 (point *e*).

higher-price items take up a larger share of consumers' budgets. At a high enough price, all demand curves eventually become elastic, including life-saving drugs. *On a linear demand curve, the top half of the demand curve is price elastic, while the bottom half is price inelastic.*

Total Revenue Is Maximized at Unit Elasticity By now, you should recognize that businesses can increase total revenue whenever their product is price inelastic. Along a linear demand curve, however, higher prices can only raise revenue up to the point where the product is unit elastic. Raising price above $5 lowers total revenue. This means that total revenue is maximized at the point of unit elasticity. If we look at the midpoints of the price and quantity for which unit elasticity occurs (price of $6 and

$4; quantity of 4 and 6), we find a price of $5 and a quantity of 5. At this point, total revenue equals $25 ($5 × 5). No other point would lead to a higher total revenue.

The Goal of Firms Is to Maximize Profits, Not Total Revenue While revenue is important, the goal of firms is to maximize *profit,* which is equal to total revenue minus total cost. Selling more units typically involves increasing the cost of doing business. The marginal analysis introduced in Chapter 1 suggests that it is foolish for Mario to sell one more pizza at $5 if it cost $15 to make; revenue might increase, but at the end of the day, he would be spending more money than he will get in return. Although there are some cases where revenue maximization is completely consistent with profit maximization—Amazon, for example, can sell additional e-book downloads with virtually no additional costs for producing, warehousing, or shipping—in most cases firms do incur extra costs, and thus profit maximization is not the same as revenue maximization. We will discuss profit maximization further in the chapter on perfect competition.

4.4 OTHER DEMAND ELASTICITIES

In addition to understanding the responsiveness of their customers to price changes, businesses must understand the responsiveness of their customers to other variables, including changes in consumers' income and changes in the price of other products. In this section, we'll examine how the concept of elasticity can be used to estimate the degree to which factors other than price affect the quantity demanded.

Income Elasticity of Demand

Income elasticity of demand is a measure of how responsive quantity demanded is to changes in consumers' income; it equals the percentage change in quantity demanded divided by the percentage change in income. Mathematically, it is

$$E_{\text{income}} = \frac{\text{Percentage change in } Q_d}{\text{Percentage change in income}}$$

or

$$E_{\text{income}} = \frac{\%\Delta Q_d}{\%\Delta\text{income}}$$

The main difference between this formula and the formula for the price elasticity of demand is that we are analyzing the impact of changes in income. Note that in the case of income elasticity, the positive (+) or negative (−) sign is important.

As we discussed in Chapter 3, *inferior goods* are goods for which demand decreases as incomes increase and demand increases as incomes decrease. Because income and quantity demanded move in opposite directions, inferior goods have a negative income elasticity of demand. When incomes increase, the sign of the denominator (%Δincome) is positive, and since quantity demanded decreases, the sign of the numerator ($\%\Delta Q_d$) is negative. Foods like potatoes and hot dogs tend to be inferior goods—more likely to be consumed as incomes decline and by the poor rather than the affluent.

Most goods, however, are not inferior goods. As discussed in Chapter 3, most goods see an increase in demand when incomes increase and vice versa. A *normal good* is a good for which demand increases as incomes increase, and demand decreases as incomes decrease. Because income and quantity demanded both move in the same direction, normal goods have a positive income elasticity of demand. When incomes increase, the sign of the denominator (%Δincome) is positive, and since quantity demanded also increases, the sign of the numerator ($\%\Delta Q_d$) is also positive. Goods ranging from apples to automobiles to airplanes tend to be normal goods.

income elasticity of demand A measure of how responsive quantity demanded is to changes in consumers' income; it equals the percentage change in quantity demanded divided by the percentage change in income.

Among normal goods, income elasticities can vary greatly. Luxuries like cruises, fine wine, and yachts tend to be more income elastic than necessities like food and televisions. **Income elastic demand** means the income elasticity of demand is greater than 1. Luxury goods are said to be income elastic. For a good to be income elastic, the numerator ($\%\Delta Q_d$) must be greater than the denominator ($\%\Delta$income). This means the quantity demanded of luxury goods increases more rapidly than incomes. As incomes rise, the average spending on such goods goes from essentially zero to a steadily larger percentage of the budget. To be a luxury good, it's not enough for people to buy more as incomes rise; they must spend a bigger *percentage* of their income on the good as income rises.

Normal goods can also be income inelastic. **Income inelastic demand** means the income elasticity of demand falls between 0 and 1. As we discussed earlier in this chapter, price changes have little impact on the quantity of necessities (such as gasoline or milk) sold—necessities tend to be price inelastic. Likewise, such necessities are often *income inelastic*. As incomes change, spending on basic groceries and gasoline tends to rise, but by a smaller percentage. As such, these goods become a smaller share of one's budget.

POLICY BRIEF Public Transportation in Singapore

In 2011, economists in Singapore conducted a study to examine the effect of income on the demand for different transportation options in that city. They found that when incomes fall by roughly 4%, the use of public transportation increases by 1%. Mathematically, the income elasticity of demand is

$$E_{\text{income}} = \frac{.01}{-.04} = -0.25$$

This suggests that public transportation is an inferior good. That same study estimated the income elasticity of automobile ownership in Singapore to be 0.59; the positive number suggests automobiles are a normal good, as one might expect. They are also income inelastic. When Singaporeans get a 10% raise, they tend to spend an extra 5.9% on cars and 2.5% less on public transport. Such economic studies provide policymakers with useful data for setting transportation policy. Here, the income elasticities suggest that a booming economy may reduce the use of public transportation and increase congestion on roadways. Singapore responded with a heavy tax on cars, to reduce traffic congestion.*

*Michael Z. F. Li, Daren C. B. Lau, and Daniel W. M. Seah, "Car Ownership and Urban Transport Demand in Singapore," *International Journal of Transport Economics = Rivista Internazionale di Economia dei Trasporti*, January 31, 2011, http://trid.trb.org/view.aspx?id=1102691.

BUSINESS BRIEF Income Elasticity and U.S. Auto Sales

Consider three automobiles: the Ford Focus (a compact car), the Toyota Camry (a family sedan), and the Porsche 911 (a luxury sports car). Can you guess which car was hardest hit by the Great Recession (2007–2009), during which median incomes fell roughly 4%? Sales data along with income elasticity estimates (based on raw data) are presented in Exhibit 6.

It is not surprising that the Porsche 911 was very responsive to income changes. But as you can see, the sales of the Focus fell 7%, suggesting an income elasticity of roughly 1.75. This suggests that, even an economy car like the Ford Focus was considered a luxury good during the severe downturn of the Great Recession, as its income elasticity was greater than 1.

income elastic demand An income elasticity of demand that is greater than 1.

income inelastic demand An income elasticity of demand that is between 0 and 1.

Recall that economists apply the *ceteris paribus* assumption when analyzing data. In the real world, other things are not always equal, and many changes occur almost all the time. For example, you may recall from Chapter 3 that sales of the Ford Focus rose in 2008 due, in part, to increases in gasoline prices. However, in 2009, gasoline prices fell back to 2007 levels of roughly $3 a gallon, but auto sales did not recover. By 2009, the dominant factor affecting car sales was falling incomes during a severe recession. Not only were incomes falling, many potential consumers across all income levels feared *potential* losses in income: Unemployment was rising and those with investments in stocks or real estate saw sharp losses. With all of these changes occurring at once, it is often difficult to arrive at precise income elasticity estimates. However, most studies suggest that automobile sales are a normal good ($E_{\text{income}} > 0$).*

EXHIBIT 6 Rough Estimates of Income Elasticities of Select Cars (2007–2009)

	Ford Focus	Toyota Camry	Porsche 911
2007 U.S. Sales	173,213	473,108	12,497
Percentage Change by 2009	−7%	−25%	−45%
Income Elasticity	1.8	6	11

Between 2007 and 2009, incomes fell by roughly 4%, while automobile sales dropped dramatically. Presented here are sales data for the Ford Focus, Toyota Camry, and Porsche 911. Gasoline prices started and finished at roughly the same price. Thus, the price of gasoline was not a major factor in determining sales during this period.

*Timothy Cain, "Ford Focus Sales Figures" and "Toyota Camry Sales," *GoodCarBadCar.com*, January 2, 2011, http://www.goodcarbadcar.net/2011/01/toyota-camry-sales-figures.html.

Cross-Price Elasticity of Demand

As you'll recall from Chapter 3, some products are related: When the price of one item changes, the demand for a related good changes as well. **Cross-price elasticity of demand** is a measure of how responsive quantity demanded is to changes in the price of another product; it equals the percentage change in quantity demanded of one product divided by the percentage change in price of another product. Mathematically, it is

$$E_{\text{cross price}} = \frac{\text{Percentage change in } Q_d}{\text{Percentage change in price of another product}}$$

or

$$E_{\text{cross price}} = \frac{\%\Delta Q_d}{\%\Delta P_{\text{another product}}}$$

As with income elasticity, the estimated value of the cross-price elasticity of demand can be positive or negative. An increase in the price of a secondary good can increase, decrease, or have no impact on the quantity of the primary good sold.

Recall that *complements* are a pair of products that are usually consumed together, and for which an increase in the price of one good reduces the demand for the other good, and vice versa. Thus by definition, complements have a cross-price elasticity that is negative. For example, if the price of pizzas falls, then the demand for toppings increases (as more pizzas are sold).

Conversely, substitute goods have a positive cross-price elasticity: An increase in the price of a secondary good can have a positive impact on the sales of the primary good. Recall, *substitutes* are defined as a pair of products for which an increase in the price of one leads to an increase in the demand for the other, and vice versa. Substitutes can be viewed as two products that are alternatives to each other. Substitute goods have a cross-price elasticity that is positive.

cross-price elasticity of demand A measure of how responsive quantity demanded is to changes in the price of another product; it equals the percentage change in quantity demanded of one product divided by the percentage change in price of another product.

EXHIBIT 7 Income and Cross-Price Elasticities for Different Types of Goods

Panel A: Income Elasticities

Type of Good	Values	Examples
Inferior	$E_{income} < 0$	Potatoes, basic wireless phones
Normal (necessity)	$0 < E_{income} < 1$	Basic groceries and medicine
Normal (luxury)	$E_{income} > 1$	Cars such as a Bentley or Ferrari

Panel B: Cross-Price Elasticities

Type of Good	Values	Examples
Complement	$E_{cross\text{-}price} < 0$	Pizza and toppings
Unrelated Goods	$E_{cross\text{-}price} = 0$	Roses and chalk
Substitute	$E_{cross\text{-}price} > 0$	McDonald's and Pizza Hut

Inferior goods have a negative income elasticity of demand, while normal goods have a positive income elasticity of demand. Complement goods have a negative cross-price elasticity of demand, while substitute goods have a positive cross-price elasticity of demand.

For example, data suggest that when prices go up by 10% at McDonald's, sales at Pizza Hut increase by 0.7%. The cross-price elasticity is 0.07. Ten percent price increases at Subway, Burger King, Wendy's, and KFC result in an approximate 0.2% increase in Pizza Hut sales. These positive cross-price elasticity estimates suggest that various fast-food restaurants are indeed substitute products. Note, however, that a 10% price increase at Pizza Hut has a considerably smaller impact on the sales of its larger rivals, because cross-price elasticity estimates are not symmetrical.

The fact that the cross-price elasticity estimates are relatively small suggests that price changes at one particular fast-food restaurant do not have a significant impact on sales at another *particular* restaurant, as there are many other alternatives. Cross-price elasticity measurements would tend to be larger if localized within specific towns and cities, as opposed to across an entire nation.[1]

Key values of income and cross-price elasticities of demand can be found in Exhibit 7.

BUSINESS BRIEF Cross-Price Elasticity of Demand Between Natural Gas and Coal

Natural gas prices fell by two thirds between 2008 and 2013 as fracking increased supply. This prompted many electric power companies to switch from burning coal—traditionally, the cheapest fuel—to natural gas, a substitute that was now less expensive. This switch reduced the demand for coal by 17.5% between 2008 and 2013.* In this case, the cross-price elasticity of demand can be estimated as

$$E_{cross\text{-}price} = \frac{\%\Delta Q_d}{\%\Delta P_{another\ product}} = \frac{-17.5\%}{-67\%} = 0.3$$

The increased use of natural gas and decreased use of coal in the generation of electricity contributed to a 10% decrease in the greenhouse-gas emissions from U.S. power plants between 2010 and 2012.† This resulted because natural gas emits far fewer greenhouse gases than coal. It is now estimated that natural gas will be used to produce a third of all U.S. electricity by 2020, compared with just over 20% in 2008.

*"From Sunset to New Dawn," *The Economist,* November 18, 2013, http://www.economist.com/news/business/21589870-capitalists-not-just-greens-are-now-questioning-how-significant-benefits-shale-gas-and.

†U.S. Energy Information Administration, "Annual Energy Review," 2011, http://www.eia.gov/totalenergy/data/annual/index.cfm.

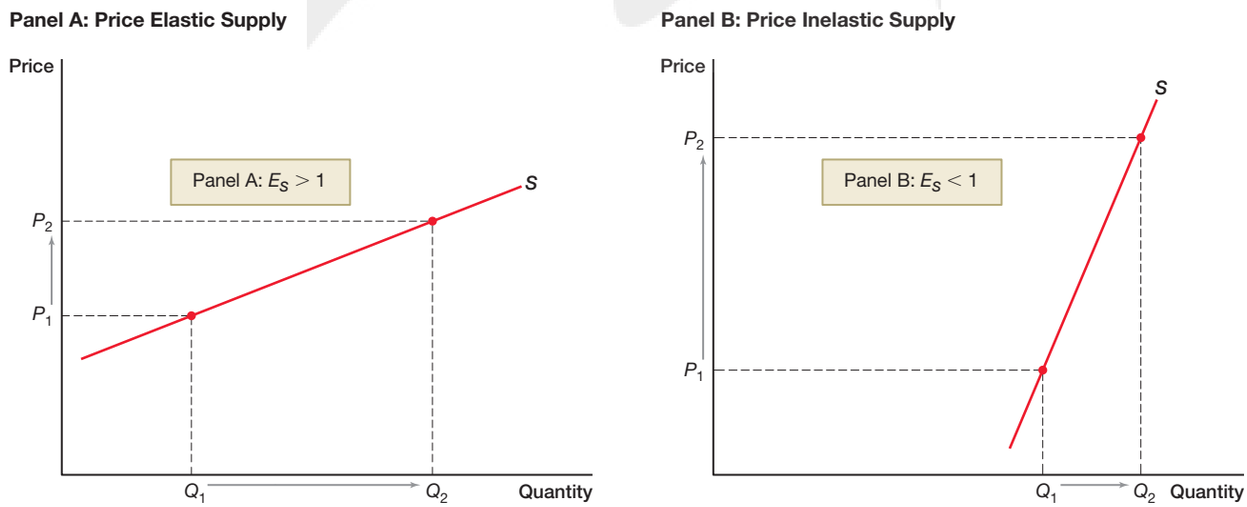
4.5 PRICE ELASTICITY OF SUPPLY

Businesses are also responsive to price changes. Recall from Chapter 3 that the supply curve shows us that when the price of a product increases (due to an increase in demand), so, too, does the quantity supplied. This is because sellers respond to higher prices with increased output. But *how much* does output increase? For example, suppose the hourly price of a Web design service increases by 10% due to an increase in demand—the quantity of hours supplied will increase. Price elasticity of supply tells us how large the increase will be.

Price elasticity of supply (E_s) is a measure of how responsive quantity supplied is to price changes; it equals the percentage change in quantity supplied divided by the percentage change in price. In Exhibit 8, the good in Panel A is relatively responsive to price changes and is considered elastic. The supply of pizzas is fairly price elastic, especially in the long run. The good in Panel B is not very responsive to price changes and is considered inelastic. For example, in the short run, raw materials like crude oil have a steeply sloping supply curve.

price elasticity of supply (E_s) A measure of how responsive quantity supplied is to price changes; it equals the percentage change in quantity supplied divided by the percentage change in price.

EXHIBIT 8 Elastic and Inelastic Supply Curves



In Panel A, the supply curve is price elastic. Here, quantity is responsive to a price change: Small price changes lead to large changes in quantity. Conversely, in Panel B, the supply curve is price inelastic: Quantity is not very responsive to price changes.

How Much Quantity Supplied Changes When Price Changes

The formula for calculating price elasticity of supplied is similar to other elasticity formulas presented earlier in the chapter. Mathematically, it is the percentage change in quantity supplied divided by the percentage change in price. That is,

$$E_s = \frac{\text{Percentage change in } Q_s}{\text{Percentage change in } P}$$

or

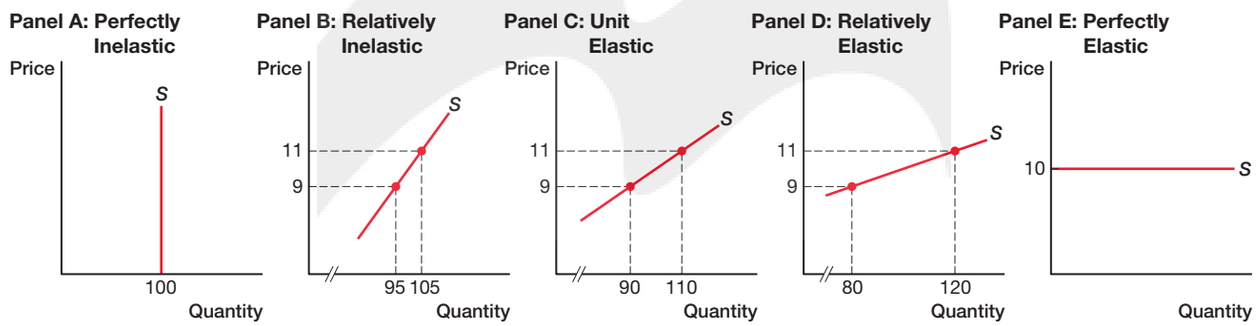
$$E_s = \frac{\%\Delta Q_s}{\%\Delta P}$$

The equation is similar to that of the price elasticity of demand, except price elasticity of supply uses data from the supply curve. Estimates of the price elasticity of supply can range from zero to infinity:

- $E_s = 0 \rightarrow$ perfectly inelastic supply
- $E_s < 1 \rightarrow$ inelastic supply
- $E_s = 1 \rightarrow$ unit elastic supply
- $E_s > 1 \rightarrow$ elastic supply
- $E_s =$ infinity $\rightarrow$ perfectly elastic supply

Exhibit 9 shows the range of values for the price elasticity of supply. Panel A shows a perfectly inelastic supply curve. It is a vertical line. In contrast, Panel E shows that a perfectly elastic supply curve is a horizontal line.

EXHIBIT 9 Graphical Summary of the Price Elasticity of Supply



Panel A	Panel B	Panel C	Panel D	Panel E
$E_s = 0$ $\%\Delta Q = 0$	$E_s < 1$ but not 0 $\%\Delta Q < \%\Delta P$	$E_s = 1$ $\%\Delta Q = \%\Delta P$	$E_s > 1$ but not infinity $\%\Delta Q > \%\Delta P$	$E_s =$ infinity $\%\Delta P = 0$
$E_s = \frac{\%\Delta Q}{\%\Delta P} = 0$	$E_s = \frac{10\%}{20\%} = 0.5$	$E_s = \frac{20\%}{20\%} = 1$	$E_s = \frac{40\%}{20\%} = 2$	$E_s = \frac{\%\Delta Q}{\%\Delta P} =$ infinity

$E_s = 0$ • $E_s = 1$ • $E_s =$ infinity

Less responsive ***More responsive***

Estimates of the price elasticity of supply can range from zero (perfectly inelastic) to infinity (perfectly elastic).

BUSINESS BRIEF The $1 Million Parking Space

Occasionally, an item has an almost perfectly inelastic supply: The supply of land, for example, is often drawn as a vertical line, as it is generally fixed by nature and hence perfectly inelastic. When supplies are fixed, the primary determinant of price

is demand: The quantity supplied cannot change. Consider parking spaces near a ballpark or arena. The number of parking spots available nearby is the same, whether there is an event occurring or not. But as you may have guessed, prices change quite a bit, depending on what's ongoing at that venue. Near Fenway Park in Boston, parking can cost upward of $50 during a Red Sox game, and as little as a few quarters in a parking meter at other times.* The high price of parking stems from the limited supply of land near the ballpark, and high demand for parking on game nights.

But what happens when demand for parking *always* outpaces supply? In some parts of New York City, for example, parking spaces are scarce around the clock. Commuters seeking to park for a few hours on any given day will pay as much as a Red Sox fan looking for a spot near Fenway on game night. As such, some very wealthy New Yorkers are willing to *buy* parking spots—for as much as a million dollars. Why? Once again, supply is limited and highly inelastic—and when this occurs, the primary determinant of price is demand.

Finally, the lucky buyer of the million dollar spot does have the option of increasing supply. As the *New York Post* pointed out, "The spot could be 'duplexed' if the buyer decides to install an elevator lift so he or she can slide both the Maserati and the Lamborghini in at the same time."† What a deal!

*"Fenway Park: Parking," *MLB.com,* n.d., accessed May 11, 2017, http://boston.redsox.mlb.com/bos/ballpark/directions/index.jsp?content=parking.

†Annie Karni, "The $1 Million Parking Space," *New York Post,* May 20, 2012, http://nypost.com/2012/05/20/the-1-million-parking-space/.

Factors That Influence Price Elasticity of Supply

Several factors determine the price elasticity of supply. These include the time it takes businesses to adjust their inputs and how much it costs to increase output.

Time to Adjust Inputs The short- and long-run distinction is even more significant on the supply side than the demand side. In general, the more time businesses have to adjust, the greater the price elasticity of supply. Three distinct time frames exist:

- *Immediate future or market day.* In the very short run, the supply may be almost perfectly inelastic. For example, consider a fisherman who fishes every morning and sells his catch in the afternoon. A change in the price of fish has no impact on the quantity of fish supplied that day, which must be sold before they spoil. Likewise, if Mario makes 1,000 slices of pizza for a carnival later that night, he cannot change his quantity supplied if demand is higher than expected.
- *The short run.* If slightly more time elapses—say, a couple of days—the higher price of fish or pizza will encourage the fisherman to work more hours or Mario to make more pizza. In the short run, however, Mario will still be constrained by the number of ovens he has available and the fisherman by the number of his boats.
- *The long run.* Remember that the long run refers to the length of time necessary to make *all* adjustments to economic circumstances. Over time, Mario can respond to higher prices by hiring more staff and expanding his pizza shop, or he might open another restaurant. The fisherman can buy additional boats

▼ Looking for a place to park? It will cost you.

Kit Leong/Shutterstock.com

and hire additional crew. More importantly, the long run is enough time for new firms to enter the industry. Most industries have an extremely elastic supply in the long run.

Think & Speak Like an Economist

In economics, it is important to consider both the long run and the short run. Both price elasticity of supply and price elasticity of demand are typically higher (more elastic) in the long run, as businesses and consumers have more time to adjust.

Marginal Cost of Increasing Output When the marginal costs to make an additional few units is rising as output rises, supply will tend to be less price elastic (more inelastic). This is typically the case when a business is at capacity. Consider the example of an automobile manufacturer such as General Motors or Ford. Once a factory is built and running at capacity, it is expensive to manufacture a few more automobiles, because if the process runs overtime, the wages paid will generally be higher.

In contrast, when the marginal cost to make an additional few units is stable, the supply will tend to be more price elastic. This will likely be the case when there is spare capacity. A Ford factory running below capacity will not find it overly expensive to operate a few more hours per day, and a Dunkin' Donuts franchise not at capacity can quickly bake extra donuts when demand is growing.

Fixed Quantity Supplied Some items such as collectibles and land have a fixed quantity supplied that cannot be changed easily, even in the long run. In this case, the price elasticity of supply is perfectly inelastic. Consider the case of a Stradivarius violin. The supply curve for such a violin is a vertical line, as shown in Exhibit 9 as $E_s = 0$. Why? Because Antonio Stradivari died in 1737—no more can be made. Similarly, land also has a fixed quantity supplied. The previous Business Brief explains how such a scenario can result in seemingly exorbitant prices for parking spaces.

CASE STUDY Why Are Gas and Oil Prices So Unstable?

During 2008 and 2009, the price of crude oil fluctuated wildly, from about $40 per barrel to $147 per barrel. Consumers were bewildered as gasoline prices soared to $4 per gallon in 2008, then plunged to $2 in 2009, then recovered to the $3 to $4 range over the next few years, before falling back to the $2 range in 2015 to 2017. Why are crude oil prices so unstable? The underlying causes are all related to the price inelastic nature of supply and demand of crude oil.

Although alternative sources of energy such as wind and solar appear promising, oil remains the primary source of energy in the world economy. The price of gasoline typically follows the price of oil, as crude oil is the most important input into gasoline. According to the economist James Hamilton who studies energy economics, a gallon of gasoline in the United States costs, on average, roughly 84 cents plus 2½% of the price of a barrel of crude oil (or Brent crude oil). If you hear a business reporter saying that crude oil is $100 per barrel, you can expect gasoline to soon cost *about* $3.34 per gallon ($0.84 + $2.50). Basically, it costs a relatively constant 84 cents per gallon to cover fairly constant transportation, refining, and distribution cost. The 2.5% covers the cost of crude, which changes on a regular basis. The actual price you pay will vary depending on factors such as state and local taxes and the degree of competition.

As we discussed at the beginning of this chapter, the demand for oil and related products like gasoline is relatively price inelastic, particularly in the short run. In the immediate aftermath of an increase in the price of oil, automobiles are still driven, homes are still heated, and electricity is still generated. But in the long run, consumers are more responsive to changes in the price of oil and gasoline—that is, price elasticity of demand is higher in the long run. In response to continually higher fuel prices, consumers will gradually find ways to conserve energy. They'll walk, bike, carpool, or use public transportation more often. When practical, they will opt for more fuel-efficient cars; some might move closer to work, or to public transportation hubs.

The supply of oil is also price inelastic. Large and easily accessible crude oil reserves are quite limited. There are relatively low-cost supplies in the Persian Gulf region of the Middle East, where nearly half of the world's conventional oil reserves are located. When demand for oil rises, however, new production must take place in areas where it is often more difficult and costly to produce oil. Sometimes the difficulty stems from political instability, as is frequently the case with oil from the Middle East and Africa. In other regions, the difficulty is often technical, as is the case in remote areas of Alaska and Canada, and with offshore oil reserves

located far below the Gulf of Mexico and North Sea. However, when these expensive wells are functioning, the cost of continuing to produce oil is low, compared to the cost of drilling a new well. This means that when oil prices fall, companies tend to keep producing from existing wells but are less likely to drill new wells. All these factors make the supply of oil relatively price inelastic at current output levels.

The key characteristics of the oil market include:

- Price inelastic demand in the short run
- Price inelastic supply in the short run
- Oil often produced in areas that are politically volatile or difficult to access
- Supply subject to disruptions

Price Inelastic Supply and Demand Result in Large Price Swings

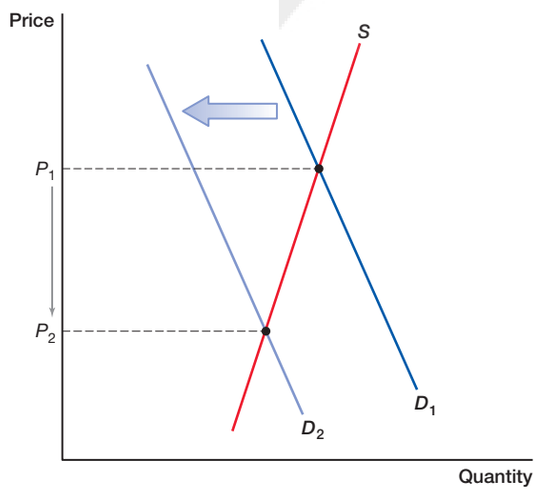
With both supply and demand being price inelastic, relatively small shifts in the supply or demand for oil can have a very large impact on prices. Motorists notice this instability every time they fill up at the gas pump. For example, in 2007 and 2008, rapid growth in developing countries such as China led to a sharp increase in oil demand. The global demand curve for oil shifted to the right. This raised price sharply, but quantity supplied only increased by a very small amount because the supply of oil in the short run is very inelastic. So even though producers earned much higher prices in 2008, they only were able to slightly increase production. When the demand for oil suddenly declined in late 2008 as a result of the Great Recession, the price of oil fell sharply (70%).*

Exhibit 10 demonstrates a price inelastic supply and demand curve and the effects of a decline in demand. Likewise, Exhibit 11 shows how even a small decrease in supply shifts the supply curve to the left can result in a relatively large increase in the price of oil. Such supply "shocks" can result from natural or man-made disasters, from political instability or political maneuvering. In 1973, for example, the Organization of the Petroleum Exporting Countries (OPEC) slashed oil production, in retaliation for the United States' support of Israel in a military conflict in the Middle East, dramatically raising the price per barrel overnight. Soon thereafter, OPEC instituted an embargo that cut off the supply of Middle Eastern oil to the United States entirely. In three months, the price of oil tripled.†

Finally, recall that the long-run supply and demand price elasticities are greater than the short-run price elasticities. In the short run, the oil price hike of 2008 did not produce an immediate increase in global oil output. However, over the next few years, American producers responded to higher prices by investing in new technologies and alternative energy sources.

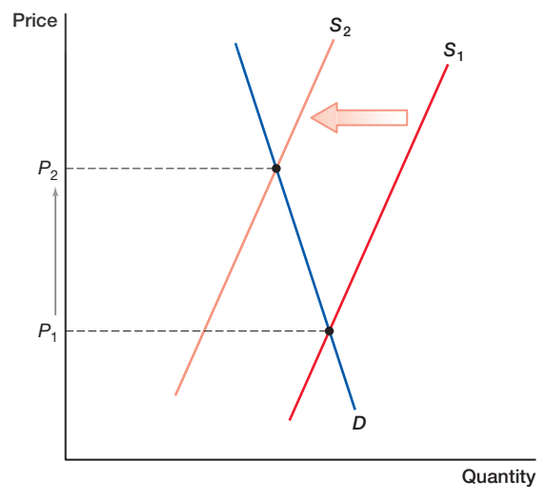
As noted earlier, increased use of fracking technology boosted the output of oil and natural gas. Alternative energy sources—such as solar and wind—have also begun to gain some traction in recent years. In 2013, over $200 billion was invested globally in renewable energy, with over half of that total pumped into solar. So intense was the expansion that more

EXHIBIT 10 Decrease in the Demand for Oil



Since the supply and demand curves for oil are both inelastic, a decrease in demand can lead to a large price change.

EXHIBIT 11 Decrease in the Supply of Oil



Since the supply and demand curves for oil are both inelastic, a decrease in supply can lead to a large price change.

solar capacity was developed between 2010 and 2014 than in the previous four decades combined. However, even at this breakneck pace, solar is expected to make up just 2 to 3% of the global electricity market in coming years.[‡] Similarly, consumers can and do eventually switch to more fuel-efficient cars and insulate their homes more efficiently when prices remain high. Remember, time to adjust is a critical factor in determining the price elasticity of demand. The demand for oil is more elastic in the long run than in the short run.

[*]See James D. Hamilton, "Understanding Crude Oil Prices," *The Energy Journal* 30, no. 2, 2009: 179–206; and James D. Hamilton and Menzie Chinn, "Gasoline Prices Coming Down," *econbrowser.com,* June 24, 2012, http://econbrowser.com/archives/2012/06/gasoline_prices_7.

[†]OPEC, U.S. Energy Information Administration, http://www.opec.org/opec_web/static_files_project/media/downloads/publications/ASB2013.pdf, http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=emm_epm0_pte_nus_dpg&f=w.

[‡]Shawn Tully, "The Shale Oil Revolution Is in Danger," *Fortune.com,* January 9, 2015, http://fortune.com/2015/01/09/oil-prices-shale-fracking/; and "We Make Our Own," *The Economist,* January 15, 2015, http://www.economist.com/news/special-report/21639020-renewables-are-no-longer-fad-fact-life-supercharged-advances-power.

BUSINESS TAKEAWAY

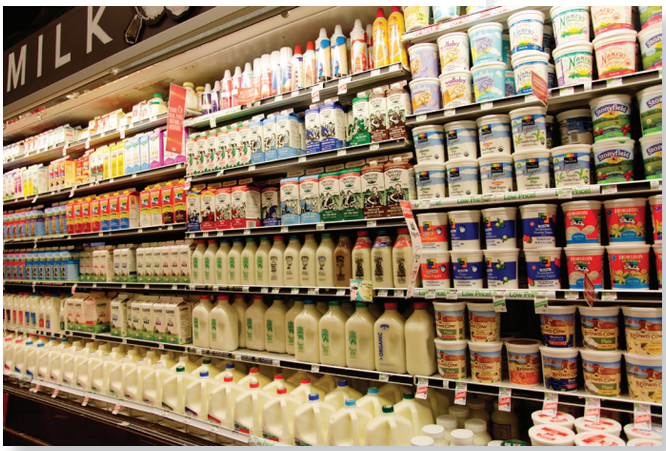
As demonstrated in our examination of Amazon's dispute with Hachette, the economic concept of elasticity has clear applications in business: Amazon demonstrated that its customers were highly responsive to changes in the price of e-books, and that lower prices could and did result in higher revenues. As firms become increasingly data-driven, they will be able to access vast troves of information on quantities sold at different prices, which they can then analyze to determine real-world elasticities and to set optimal prices.

Many firms employ economists to estimate demand elasticities and calculate cross-elasticities to find out which goods are substitutes and complements with sometimes surprising results. A firm selling a product for which there are no good substitutes can take advantage of price inelastic demand: Because consumers are relatively unresponsive to price changes when demand is price inelastic, such firms can easily increase price, without seeing a large decline in sales. Such a price increase is particularly appealing to the firm, as not only does total revenue increase, the firm also sells slightly fewer units, and thus has slightly lower costs. This increases profitability, even as fewer units are sold.

Most businesses, however, sell products that have *a lot* of substitutes—they compete with other brands, and with similar or alternative products. Although the overall demand for milk is price inelastic, the demand for any specific brand of milk is highly elastic. This means that individual firms usually face a demand curve that is highly elastic. In such cases, even a modest price increase will lead to a comparatively large decrease in sales and a decrease in total revenue.

When measuring price elasticities, it's important to distinguish between the demand curve facing a single product line, or a single firm, and the demand curve facing an entire industry. An independent farmer understands that the demand for her organic milk will be more price elastic than the demand for organic milk in general. In turn, this specific type of milk will be more price elastic than the overall market demand for milk.

That same farmer, of course, might seek ways to change the demand curve for her organic milk. Firms big and small advertise in hopes of both increasing the demand for their product and changing the price elasticity of demand for the goods or services they offer. A successful marketing and advertising plan can make consumers less responsive to price changes. A firm might convince consumers that certain products are necessities rather than luxuries, or that alternative products are not good substitutes, making demand less elastic.



foodfolio/Alamy Stock Photo

Got milk? Consumer demand for milk is generally price inelastic, but specific brands of milk are highly elastic.

Firms benefit when they are able to capitalize on the income elasticity of goods in different market segments. A firm that sells both inferior and normal goods appeals to a wider range of customers at different income levels. Such firms will also be better positioned to weather recessions, when incomes typically fall, and consumer spending shifts toward inferior goods.

Firms can increase revenues if they make strategic decisions related to cross-elasticities among the goods and services they offer. For example, Hewlett-Packard or Brother might sell printers at a loss, in order to lock in future sales on more profitable complement goods, such as printer drums and toner cartridges. Cross-elasticities also occur between different firms: Every time Apple or Samsung releases a new device, for example, a bevy of small firms that sell complement goods such as chargers, cases, earbuds, and applications are also likely to see an increase in demand.

CHAPTER STUDY GUIDE

4.1 THE PRICE ELASTICITY OF DEMAND

Elasticity is a measure of responsiveness, with price elasticity of demand being a measure of how responsive quantity demanded is to price changes. The **price elasticity of demand (E_d)** depends on the availability of substitutes, the amount of time to adjust, the share of budget spent on the product, and whether the good is a necessity, a luxury, addictive, or heavily advertised with brand loyalty. In general, demand is more elastic and consumers are more responsive to price changes the greater the number of substitutes, the more time to adjust, the larger the share of one's budget spent on the item, and when goods are luxuries.

4.2 MEASURING THE PRICE ELASTICITY OF DEMAND

Price elasticity of demand is measured as percentage change in quantity over percentage change in price. Percentage changes are measured using the midpoint formula—change in value over average value. Thus,

$$E_d = \frac{\%\Delta Q_d}{\%\Delta P} = \frac{\left(\dfrac{\Delta Q}{(Q_1 + Q_2)/2}\right)}{\left(\dfrac{\Delta P}{(P_1 + P_2)/2}\right)}$$

Depending on the source, price elasticity of demand is expressed as a positive or negative number. When demand is price elastic, that is, $E_d > 1$, consumers are relatively responsive to price changes, and thus any given change in price will lead to a proportionally larger change in quantity demanded. When demand is price inelastic and $E_d < 1$, consumers are not very responsive to price changes.

4.3 HOW A PRICE CHANGE AFFECTS UNIT SALES AND SALES REVENUE

Price changes impacts both unit sales and sales revenue. Elasticity values can be used to make estimates of price and quantity changes. When the price elasticity of demand and the price change are known, quantity changes can be estimated as

$$\%\Delta Q_d = E_d \times \%\Delta P$$

Total revenue is the money a business receives for selling a product; also called *revenue*. It equals the price of the item times the quantity sold. When demand is price inelastic, increases in price increase total revenue, as the increase in price is proportionately larger than the decrease in quantity demanded. When demand is price elastic, an increase in price lowers total revenue. Total revenue is maximized at the point where demand is unit elastic.

4.4 OTHER DEMAND ELASTICITIES

Income elasticity of demand is a measure of how responsive quantity demanded is to changes in income. It equals

$$E_{d,\text{income}} = \frac{\%\Delta Q_d}{\%\Delta\text{income}}$$

If $E_{d,\text{income}} < 0$, the item is considered an inferior good. If $E_{d,\text{income}} > 0$, the item is considered a normal good. **Income elastic demand** means the income elasticity of demand is greater than 1. Luxury goods are said to be income elastic. In contrast, **income inelastic demand** means the income elasticity of demand falls between 0 and 1. Necessities are often income inelastic. **Cross-price elasticity of demand** is a measure of how responsive

quantity demanded is to changes in the prices of another product. It equals

$$E_{d,\text{cross-price}} = \frac{\%\Delta Q_d}{\%\Delta P_{\text{another product}}}$$

If $E_{d,\text{cross-price}} < 0$, the items are considered complement goods. If $E_{d,\text{cross-price}} > 0$, the items are considered substitute goods.

4.5 PRICE ELASTICITY OF SUPPLY

Price elasticity of supply (E_s) is a measure of how responsive quantity supplied is to price changes. It is

$$E_s = \frac{\%\Delta Q_s}{\%\Delta P}$$

If $E_s = 0$, the item is said to have a perfectly inelastic supply. This may occur in the very short run, such as a single day. $E_s < 1$ suggests an inelastic supply, and $E_s > 1$ suggests an elastic supply.

TOP TEN TERMS AND CONCEPTS

1. Elasticity
2. Midpoint Method
3. Perfectly Elastic and Perfectly Inelastic
4. Total Revenue
5. Cross-Price Elasticity
6. Price Elasticity of Demand
7. Price Elastic versus Inelastic Demand
8. Determinants of Price Elasticity of Demand
9. Income Elasticity
10. Price Elasticity of Supply

STUDY PROBLEMS

1. A local Wendy's franchise owner Jim wants to increase the revenue he receives by selling Frosties in July. He already knows that when he prices the dessert at $1.59, he sells 400 per day, and when he sets the price at $1.99, he sells 300 per day. What is the price elasticity of demand for the dessert? What happens to total revenue after the price increase? Are there any other factors Jim should consider?

2. Between 2007 and 2009, sales of the Hyundai Sonata fell 17% from 145,568 to 120,028, while incomes dropped by 4% (Cain, 2011).[2] Estimate the income elasticity of demand using the midpoint method. Is the good an inferior good, income elastic, or income inelastic?

3. According to a Web posting by Amazon, if customers will buy 100,000 copies of a particular e-book at $14.99, then they would purchase 174,000 copies of that same e-book at $9.99.[3] Use this data to estimate the price elasticity of demand.

4. Live Nation, America's largest concert promoter, hires an economist to determine how to maximize total revenue for concert events with limited seating. The economist suggests that for one currently popular artist, the price elasticity of demand is 0.5. For another artist, the price elasticity of demand is 2. Based on this information, what pricing strategies do you suggest that Live Nation adopt?

5. Assume that for a certain product the price elasticity of demand is 2 and the price elasticity of supply is 3.
   a. What impact will a 10% increase in price have on quantity demanded?
   b. What impact will a 10% increase in price have on quantity supplied?
   c. Explain the differences (or similarities) between your answers to a and b.

6. List and explain the factors that help determine the price elasticity of demand. List and explain the factors that help determine the price elasticity of supply.

7. In recent decades, incomes in China have been rising at about 10% per year. Suppose you are told that Chinese consumption is changing at the following rates:
   a. Rice: −2% per year
   b. Beef: +3% per year
   c. Seafood: +12% per year
   In each case, describe the income elasticity and also the general category to which the good belongs. Are these elasticities likely to be exactly the same in the United States?

8. Consider the following list of modes of transportation. Rank them in terms of income elasticity of demand. Explain your reasoning.
   - The Gulfstream G550, the best-selling private jet
   - A cross-country trip on a Greyhound bus, a public bus company
   - A Toyota Corolla, a basic automobile
   - A Maserati, a luxury sports car

9. Retailers commonly refer to the day after Thanksgiving as Black Friday. Assume one retailer, GameStop, that sells video games sees its sales increase by 20% after reducing prices by 10%. Discuss the price elasticity of demand in the video game market. Use this example to discuss complications in making such estimates.

10. Explain why perfectly inelastic demand is rare.

11. Taxes on products typically result in higher prices and lower sales. Based on what you have learned thus far, why might taxes on products that are price inelastic such as cigarettes or pharmaceuticals not have a major impact on sales, while taxes on products that are elastic such as cruises will have a major impact on sales.

12. Explain the relationship between total revenue and price along a linear demand curve. Use separate graphs showing demand and total revenue to demonstrate your answer.

13. Business software maker Oracle produces software that firms use to effectively manage their inventories up to the minute.[4] This allows the companies to instantly prioritize what products need to be manufactured when sales on the product start to pick up, without having to hold excessively large product inventories. This technique reduces costs and allows retailers to quickly supply more product. Explain what impact such techniques have on the relative price elasticity of supply.

14. When the price of pizza sold by Mario's rival fell by 10% last summer, Mario saw a 5% decline in his sales. What was the cross-price elasticity of demand between Mario and his rival?

15. In 1916, Henry Ford made the following statement to a newspaper reporter:

> There are many men who will pay $360 for a car who would not pay $440. We had in round numbers 500,000 buyers of cars on the $440 basis, and I figure that on the $360 basis we can increase the sales to possibly 800,000 cars for the year—less profit on each car, but more cars, more employment of labor, and in the end we get all the total profit we ought to make.[5]

a. If Ford's estimate was correct, what was the price elasticity of demand for his cars?

b. By how much did total revenue increase?