3 CHAPTER

Applying the Supply-and-Demand Model

Few of us ever test our powers of deduction, except when filling out an income tax form. —Laurence J. Peter

How large a tax would be necessary to reduce the number of teenagers who smoke by half? If the phone company starts charging users 10¢ per minute to connect to the Internet, would use fall enough that we would no longer call the World Wide Web the "World Wide Wait"? If the government were to intercept half the cocaine smuggled into New York City, how much would the price of cocaine rise in the short run and in the long run? We can use supply-and-demand analysis to answer such questions.

When an underlying factor that affects the demand or supply curve changes, the equilibrium price and quantity also change. Chapter 2 showed that you can predict the direction of the change—the *qualitative* change—in equilibrium price and quantity even without knowing the exact shape of the demand and supply curves. In the examples in Chapter 2, all you needed to know to give a qualitative answer was the direction in which the supply curve or demand curve shifted when an underlying factor changed.

To determine the exact amount the equilibrium quantity and price change—the *quantitative* change—you can use estimated equations for the demand and supply functions, as we demonstrated using the pork example in Chapter 2. This chapter shows how to use a single number to describe the shape of a demand or supply curve at a given price and how to use these summary numbers to obtain quantitative answers to what-if questions.

In this chapter, we examine five main topics

1. **How shapes of demand and supply curves matter:** The effect of a shock (such as a new tax or an increase in the price of an input) on market equilibrium depends on the shape of demand and supply curves.
2. **Sensitivity of quantity demanded to price:** The sensitivity of the quantity demanded to price is summarized by a single measure called the price elasticity of demand.
3. **Sensitivity of quantity supplied to price:** The sensitivity of the quantity supplied to price is summarized by a single measure called the price elasticity of supply.
4. **Long run versus short run:** The sensitivity of the quantity demanded or supplied to price varies with time.
5. **Effects of a sales tax:** How a sales tax increase affects the equilibrium price and quantity of a good and whether the tax falls more heavily on consumers or suppliers depend on the shape of the supply and demand curves.

3.1 HOW SHAPES OF DEMAND AND SUPPLY CURVES MATTER

The shapes of the demand and supply curves determine by how much a shock affects the equilibrium price and quantity. We illustrate the importance of the shape of the demand curve using the processed pork example (Moschini and Meilke, 1992) from Chapter 2. The supply of pork depends on the price of pork and the price of hogs, the major input in producing processed pork. A 25¢ increase in the price of hogs causes the supply curve of pork to shift to the left from S^1 to S^2 in panel a of Figure 3.1. The *shift of the supply curve* causes a *movement along the demand curve*, D^1, which is downward sloping. The equilibrium quantity falls from 220 to 215 million kg per year, and the equilibrium price rises from \$3.30 to \$3.55 per kg. Thus this supply shock—an increase in the price of hogs—hurts consumers by raising the equilibrium price 25¢ per kg. Customers buy less (215 instead of 220).

A supply shock would have different effects if the demand curve had a different shape. Suppose that the quantity demanded were not sensitive to a change in the price, so the same amount is demanded no matter what the price is, as in vertical demand curve D^2 in panel b. A 25¢ increase in the price of hogs again shifts the supply curve from S^1 to S^2. Equilibrium quantity does not change, but the price consumers pay rises by 37.5¢ to \$3.675. Thus the amount consumers spend rises by more when the demand curve is vertical instead of downward sloping.

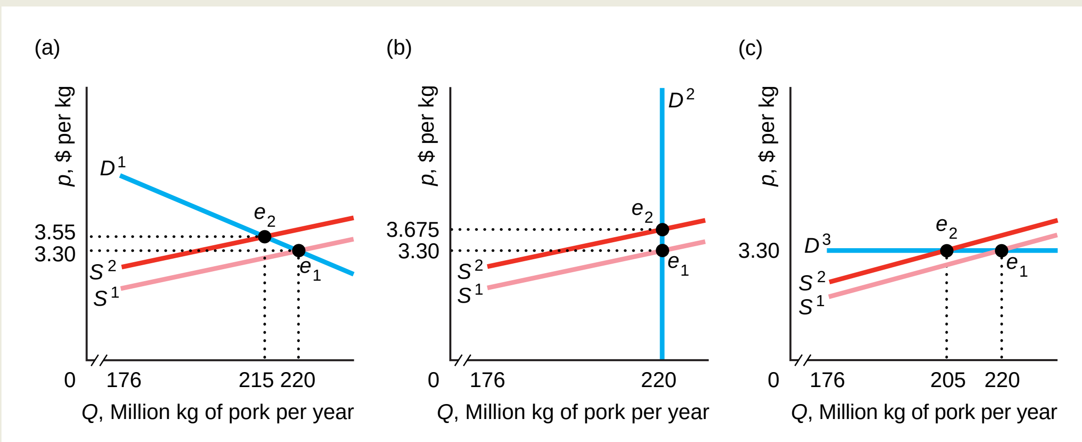

Figure 3.1 How the Effect of a Supply Shock Depends on the Shape of the Demand Curve. A decrease in the price of hogs shifts the supply of processed pork outward. (a) Given the actual downward-sloping linear demand curve, the equilibrium price rises from \$3.30 to \$3.55 and the equilibrium quantity falls from 220 to 215. (b) If the demand curve were vertical, the supply shock would cause price to rise to \$3.675 while quantity would remain unchanged. (c) If the demand curve were horizontal, the supply shock would not affect price but would cause quantity to fall to 205.

Now suppose that consumers are very sensitive to price, as in the horizontal demand curve, D^3, in panel c. Consumers will buy virtually unlimited quantities of pork at $3.30 per kg (or less), but, if the price rises even slightly, they stop buying pork. Here an increase in the price of hogs has *no* effect on the price consumers pay; however, the equilibrium quantity drops substantially to 205 million kg per year. Thus how much the equilibrium quantity falls and how much the equilibrium price of processed pork rises when the price of hogs increases depend on the shape of the demand curve.

3.2 SENSITIVITY OF QUANTITY DEMANDED TO PRICE

Knowing how much quantity demanded falls as the price increases, holding all else constant, is therefore important in predicting the effect of a shock in a supply-and-demand model. We can determine how much quantity demanded falls as the price rises using an accurate drawing of the demand curve or the demand function (the equation that describes the demand curve). It is convenient, however, to be able to summarize the relevant information to answer what-if questions without having to write out an equation or draw a graph. Armed with such a summary statistic, the pork firms can predict the effect on the price of pork and their revenues from a shift in the market supply curve.

In this section, we discuss a summary statistic that describes the shape of a demand curve at a given point. This statistic tells us how much the quantity demanded changes in response to an increase or a decrease in price. In the next section, we discuss a similar statistic that summarizes the shape of the supply curve. At the end of the chapter, we show how the government can use these summary measures for demand and supply to predict the effect of a new sales tax on the equilibrium price, firms' revenues, and tax receipts.

Price Elasticity of Demand

The most commonly used measure of the sensitivity of one variable, such as the quantity demanded, to another variable, such as price, is an **elasticity**, which is the percentage change in one variable in response to a given percentage change in another variable. We can use the *price elasticity of demand* (or simply *elasticity of demand*) to describe the shape of the demand curve. The **price elasticity of demand** is the percentage change in the quantity demanded, Q, in response to a given percentage change in the price, p. The price elasticity of demand (represented by ε, the Greek letter epsilon) may be calculated as

$$\varepsilon = \frac{\text{percentage change in quantity demanded}}{\text{percentage change in price}} = \frac{\Delta Q/Q}{\Delta p/p}, \tag{3.1}$$

where the symbol Δ (the Greek letter delta) indicates a change, so ΔQ is the change in the quantity demanded; $\Delta Q/Q$ is the percentage change in the quantity demanded; Δp is the change in price; and $\Delta p/p$ is the percentage change in price. For example, if a 1% increase in the price results in a 3% decrease in the quantity demanded, the elasticity of demand is $\varepsilon = -3\%/1\% = -3$.[1] Thus the elasticity of demand is a pure number (it has no units of measure).

It is often more convenient to calculate the elasticity of demand using an equivalent expression,

$$\varepsilon = \frac{\Delta Q/Q}{\Delta p/p} = \frac{\Delta Q}{\Delta p}\frac{p}{Q}, \tag{3.2}$$

where $\Delta Q/\Delta p$ is the ratio of the change in quantity to the change in price.[2]

We can use Equation 3.2 to calculate the elasticity of demand for a linear demand curve, which has a demand function (holding fixed other variables that affect demand) of

$$Q = a - bp,$$

where a is the quantity demanded when price is zero, $Q = a - (b \times 0) = a$, and $-b$ is the ratio of the fall in quantity to the rise in price, $\Delta Q/\Delta p$.[3] Thus for a linear demand curve, the elasticity of demand is

$$\varepsilon = \frac{\Delta Q}{\Delta p}\frac{p}{Q} = -b\frac{p}{Q}. \tag{3.3}$$

As an example, we calculate the elasticity of demand for the linear pork demand curve D in panel a of Figure 3.1. The estimated linear demand function for pork, which holds constant other factors that influence demand besides price (Equation 2.3, based on Moschini and Meilke, 1992), is

$$Q = 286 - 20p,$$

where Q is the quantity of pork demanded in million kg per year and p is the price of pork in dollars per kg. For this demand equation, $a = 286$ and $b = 20$. Using Equation 3.3, we find that the elasticity of demand at the equilibrium e_1 in panel a, where $p = \$3.30$ and $Q = 220$, is

$$\varepsilon = b\frac{p}{Q} = -20 \times \frac{3.30}{220} = -0.3.$$

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[1]Because demand curves slope downward according to the Law of Demand, the elasticity of demand is a negative number. Realizing that, some economists ignore the negative sign when reporting a demand elasticity. In the example, instead of saying the elasticity is –3, they would say that the elasticity is 3 (with the negative sign understood).

[2]When we use calculus, we use infinitesimally small changes in price (Δp approaches zero), so we write the elasticity as $(dQ/dp)(p/Q)$. When discussing elasticities, we assume that the change in price is small.

[3]As the price increases from p_1 to p_2, the quantity demanded goes from Q_1 to Q_2, so the change in quantity demanded is

$$\Delta Q = Q_2 - Q_1 = (a - bp_2) - (a - bp_1) = -b(p_2 - p_1) = -b\Delta p.$$

Thus $\Delta Q/\Delta p = -b$. (The slope of the demand curve is $\Delta p/\Delta Q = -1/b$).

The negative sign on the elasticity of demand of pork illustrates the Law of Demand: Less quantity is demanded as the price rises. The elasticity of demand concisely answers the question "How much does quantity demanded fall in response to a 1% increase in price?" A 1% increase in price leads to an ε% change in the quantity demanded. At the equilibrium, a 1% increase in the price of pork leads to a –0.3% fall in the quantity of pork demanded: A price increase causes a less than proportionate fall in the quantity of pork demanded.

Application

WEB FEES

Currently, most U.S. users pay a flat fee per month to connect to the Internet. Once connected, they can surf to their heart's content, downloading as much information as they want, at no additional cost. A typical user may download large numbers of files—Web pages, music, movies, and other information-rich material. This heavy usage slows the entire system, leading some disgruntled users to dub the World Wide Web the "World Wide Wait."

How high a price would Internet providers have to charge to substantially reduce connect time? We have some idea of the answer from observing what happened in December 1996, when America Online (AOL) and most other Internet providers switched from charging $9.95 per month for the first five hours of connect time and $2.95 per hour for every additional hour to a flat monthly rate of $19.95 for unlimited access. By 1998, average use rates for AOL had risen from 6.4 to 22.1 hours per week.

Edell and Varaiya (1999) conducted an experiment to determine how the elasticity of demand for hours of connect time with respect to the price per minute of connect time varies with the speed of the connection. Based on their experiment, Varian (1999) found that the price elasticity of demand is –1.71 at a connection speed of 64 kilobits per second (kbps) and –3.34 at 96 kbps. Unfortunately, cable broadband prices rose 12% and DSL prices rose 10% in 2001.

Elasticity Along the Demand Curve

The elasticity of demand varies along most demand curves. In this section, we show that the elasticity of demand is different at every point along a downward-sloping linear demand curve. Then we point out that the elasticities are constant along horizontal and vertical linear demand curves.

Downward-Sloping Linear Demand Curve. On strictly downward-sloping linear demand curves—those that are neither vertical nor horizontal—the elasticity of demand is a more negative number the higher the price is. Consequently, even though the slope of the linear demand curve is constant, the elasticity varies along the curve. A 1% increase in price causes a larger percentage fall in quantity near the top (left) of the demand curve than near the bottom (right).

The linear pork demand curve in Figure 3.2 illustrates this pattern. Where this demand curve hits the quantity axis ($p = 0$ and $Q = a = 286$ million kg per year), the elasticity of demand is $\varepsilon = -b(0/a) = 0$, according to Equation 3.3. Where the price is zero, a 1% increase in price does not raise the price, so quantity does not change. At a point where the elasticity of demand is zero, the demand curve is said to be *perfectly inelastic*. As a physical analogy, if you try to stretch an inelastic steel rod, the length does not change. The change in the price is the force pulling at demand; if the quantity demanded does not change in response to this pulling, it is perfectly inelastic.

For quantities between the midpoint of the linear demand curve and the lower end where $Q = a$, the demand elasticity lies between 0 and −1: $0 \geq \varepsilon > -1$. A point along the demand curve where the elasticity is between 0 and −1 is *inelastic* (but not perfectly inelastic). Where the demand curve is inelastic, a 1% increase in price leads to a fall in quantity of less than 1%. For example, at the competitive pork equilibrium, $\varepsilon = -0.3$, so a 1% increase in price causes quantity to fall by −0.3%. A physical analogy is a piece of rope that does not stretch much—is inelastic—when you pull on it: Changing price has relatively little effect on quantity.

At the midpoint of the linear demand curve, $p = a/(2b)$ and $Q = a/2$, so $\varepsilon = -bp/Q = -b(a/[2b])/(a/2) = -1$. Such an elasticity of demand is called a *unitary elasticity*: A 1% increase in price causes a 1% fall in quantity.

At prices higher than at the midpoint of the demand curve, the elasticity of demand is less than negative one, $\varepsilon < -1$. In this range, the demand curve is called *elastic*. A physical analogy is a rubber band that stretches substantially when you

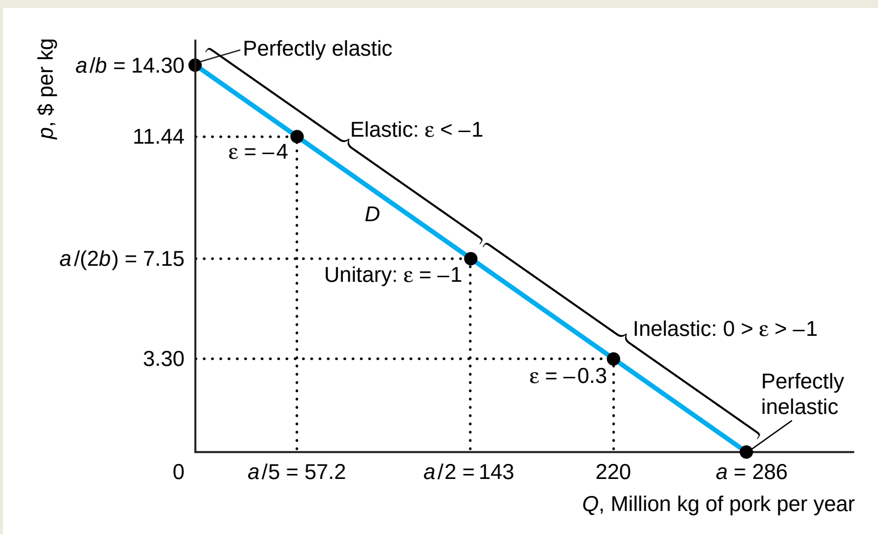

Figure 3.2 Elasticity Along the Pork Demand Curve. With a linear demand curve, such as the pork demand curve, the higher the price, the more elastic the demand curve (ε is larger in absolute value—a larger negative number). The demand curve is perfectly inelastic ($\varepsilon = 0$) where the demand curve hits the horizontal axis, is perfectly elastic where the demand curve hits the vertical axis, and has unitary elasticity ($\varepsilon = -1$) at the midpoint of the demand curve.

pull on it. A 1% increase in price causes a more than 1% fall in quantity. The figure shows that the elasticity is –4 where $Q = a/5$: A 1% increase in price causes a 4% drop in quantity.

As the price rises, the elasticity gets more and more negative, approaching negative infinity. Where the demand curve hits the price axis, it is *perfectly elastic*.[4] At the price a/b where $Q = 0$, a 1% decrease in p causes the quantity demanded to become positive, which is an infinite increase in quantity.

The elasticity of demand varies along most demand curves, not just downward-sloping linear ones. Along a special type of demand curve, called a *constant-elasticity demand curve*, however, the elasticity is the same at every point along the curve.[5] Two extreme cases of these constant-elasticity demand curves are the strictly vertical and the strictly horizontal linear demand curves.

Horizontal Demand Curve. The demand curve that is horizontal at p^* in panel a of Figure 3.3 shows that people are willing to buy as much as firms sell at any price less than or equal to p^*. If the price increases even slightly above p^*, however, demand falls to zero. Thus a small increase in price causes an infinite drop in quantity, so the demand curve is perfectly elastic.

Why would a demand curve be horizontal? One reason is that consumers view this good as identical to another good and do not care which one they buy. Suppose that consumers view Washington apples and Oregon apples as identical. They won't buy Washington apples if these sell for more than apples from Oregon. Similarly, they won't buy Oregon apples if their price is higher than that of Washington apples. If the two prices are equal, consumers do not care which type of apple they buy. Thus the demand curve for Oregon apples is horizontal at the price of Washington apples.

Vertical Demand Curve. A vertical demand curve, panel b in Figure 3.3, is perfectly inelastic everywhere. Such a demand curve is an extreme case of the linear demand curve with an infinite (vertical) slope. If the price goes up, the quantity demanded is unchanged ($\Delta Q/\Delta p = 0$), so the elasticity of demand must be zero: $(\Delta Q/\Delta p)(p/Q) = 0(p/Q) = 0$.

A demand curve is vertical for *essential goods*—goods that people feel they must have and will pay anything to get. Because Jerry is a diabetic, his demand curve for insulin could be vertical at a day's dose, Q^*. More realistically, he may have a demand curve (panel c of Figure 3.3) that is perfectly inelastic only at prices below p^*, the maximum price he can afford to pay. Because he cannot afford to pay more

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[4]The demand curve hits the price axis at $p = a/b$ and $Q = 0$, so the elasticity is $-bp/0$. As the price approaches a/b, the elasticity approaches negative infinity. An intuition for this convention is provided by looking at a sequence, where –1 divided by 1/10 is –10, –1 divided by 1/100 is –100, and so on. The smaller the number we divide by, the more negative is the result, which goes to $-\infty$ (negative infinity) in the limit.

[5]Constant-elasticity demand curves all have the form $Q = Ap^{\varepsilon}$, where A is a positive constant and ε, a negative constant, is the demand elasticity at every point along these demand curves.

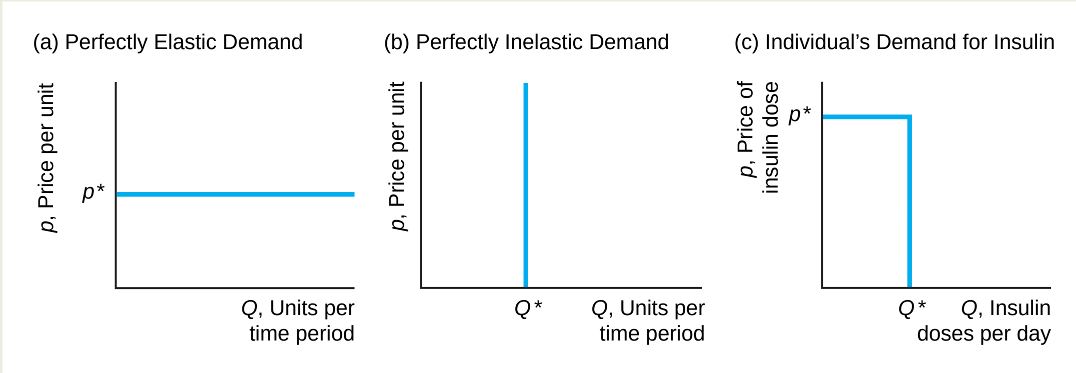

Figure 3.3 Vertical and Horizontal Demand Curves. (a) A horizontal demand curve is perfectly elastic at p^*. (b) A vertical demand curve is perfectly inelastic at every price. (c) The demand curve of an individual who is diabetic is perfectly inelastic below p^* and perfectly elastic at p^*, which is the maximum price the individual can afford to pay.

than p^*, he buys nothing at higher prices. As a result, his demand curve is perfectly elastic up to Q^* units at a price of p^*.

Other Demand Elasticities

We refer to the price elasticity of demand as *the* elasticity of demand. However, there are other demand elasticities that show how the quantity demanded changes in response to changes in variables other than price that affect the quantity demanded. Two such demand elasticities are the income elasticity of demand and the cross-price elasticity of demand.

Income Elasticity. As income increases, the demand curve shifts. If the demand curve shifts to the right, a larger quantity is demanded at any given price. If instead the demand curve shifts to the left, a smaller quantity is demanded at any given price.

We can measure how sensitive the quantity demanded at a given price is to income by using an elasticity. The **income elasticity of demand** (or *income elasticity*) is the percentage change in the quantity demanded in response to a given percentage change in income, Y. The income elasticity of demand may be calculated as

$$\xi = \frac{\text{percentage change in quantity demanded}}{\text{percentage change in income}} = \frac{\Delta Q/Q}{\Delta Y/Y} = \frac{\Delta Q}{\Delta Y}\frac{Y}{Q},$$

where ξ is the Greek letter xi. If quantity demanded increases as income rises, the income elasticity of demand is positive. If the quantity does not change as income rises, the income elasticity is zero. Finally, if the quantity demanded falls as income rises, the income elasticity is negative.

We can calculate the income elasticity for pork using the demand function, Equation 2.2:

$$Q = 171 - 20p + 20p_b + 3p_c + 2Y, \tag{3.4}$$

where p is the price of pork, p_b is the price of beef, p_c is the price of chicken, and Y is the income (in thousands of dollars). Because the change in quantity as income changes is $\Delta Q/\Delta Y = 2$,[6] we can write the income elasticity as

$$\xi = \frac{\Delta Q}{\Delta Y}\frac{Y}{Q} = 2\frac{Y}{Q}.$$

At the equilibrium, quantity $Q = 220$ and income is $Y = 12.5$, so the income elasticity is $2 \times (12.5/220) \approx 0.114$. The positive income elasticity shows that an increase in income causes the pork demand curve to shift to the right. Holding the price of pork constant at \$3.30 per kg, a 1% increase in income causes the demand curve for pork to shift to the right by 0.25 ($= \xi \times 220 \times .01$) million kg, which is about one-ninth of 1% of the equilibrium quantity.

Income elasticities play an important role in our analysis of consumer behavior in Chapter 5. Typically, goods that society views as necessities, such as food, have income elasticities near zero. Goods that society considers to be luxuries generally have income elasticities greater than one.

Cross-Price Elasticity. The **cross-price elasticity of demand** is the percentage change in the quantity demanded in response to a given percentage change in the price of another good, p_o. The cross-price elasticity may be calculated as

$$\frac{\text{percentage change in quantity demanded}}{\text{percentage change in price of another good}} = \frac{\Delta Q/Q}{\Delta p_o/p_o} = \frac{\Delta Q}{\Delta p_o}\frac{p_o}{Q}.$$

When the cross-price elasticity is negative, the goods are *complements* (Chapter 2). If the cross-price elasticity is negative, people buy less of the good when the price of the other good increases: The demand curve for this good shifts to the left. For example, if people like cream in their coffee, as the price of cream rises, they consume less coffee, so the cross-price elasticity of the quantity of coffee with respect to the price of cream is negative.

If the cross-price elasticity is positive, the goods are *substitutes* (Chapter 2). As the price of the other good increases, people buy more of this good. For example, the quantity demanded of pork increases when the price of beef, p_b, rises. From Equation 3.4, we know that $\Delta Q/\Delta p_b = 20$. As a result, the cross-price elasticity between the price of beef and the quantity of pork is

$$\frac{\Delta Q}{\Delta p_b}\frac{p_b}{Q} = 20\frac{p_b}{Q}.$$

At the equilibrium where $p = \$3.30$ per kg, $Q = 220$ million kg per year, and $p_b = \$4$ per kg, the cross-price elasticity is $20 \times (4/220) \approx 0.364$. As the price of beef rises by 1%, the quantity of pork demanded rises by a little more than one-third of 1%.

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[6]At income Y_1, the quantity demanded is $Q_1 = 171 - 20p + 20p_b + 3p_c + 2Y_1$. At income Y_2, $Q_2 = 171 - 20p + 20p_b + 3p_c + 2Y_2$. Thus $\Delta Q = Q_2 - Q_1 = 2(Y_2 - Y_1) = 2(\Delta Y)$, so $\Delta Q/\Delta Y = 2$.

Taking account of cross-price elasticities is important in making business and policy decisions. General Motors wants to know how much a change in the price of a Toyota affects the demand for its Chevy.

3.3 SENSITIVITY OF QUANTITY SUPPLIED TO PRICE

To answer many what-if questions, we need information about the sensitivity of the quantity supplied to changes in price. For example, to determine how a sales tax will affect market price, a government needs to know the sensitivity to price of both the quantity supplied and the quantity demanded.

Elasticity of Supply

Just as we can use the elasticity of demand to summarize information about the shape of a demand curve, we can use the elasticity of supply to summarize information about the shape of a supply curve. The **price elasticity of supply** (or *elasticity of supply*) is the percentage change in the quantity supplied in response to a given percentage change in the price. The price elasticity of supply (η, the Greek letter eta) is

$$\eta = \frac{\text{percentage change in quantity supplied}}{\text{percentage change in price}} = \frac{\Delta Q/Q}{\Delta p/p} = \frac{\Delta Q}{\Delta p}\frac{p}{Q}, \tag{3.5}$$

where Q is the *quantity supplied*. If $\eta = 2$, a 1% increase in price leads to a 2% increase in the quantity supplied.

The definition of the elasticity of supply, Equation 3.5, is very similar to the definition of the elasticity of demand, Equation 3.1. The key distinction is that the elasticity of supply describes the movement along the *supply* curve as price changes, whereas the elasticity of demand describes the movement along the *demand* curve as price changes. That is, in the numerator, supply elasticity depends on the percentage change in the *quantity supplied*, whereas demand elasticity depends on the percentage change in the *quantity demanded*.

If the supply curve is upward sloping, $\Delta p/\Delta Q > 0$, the supply elasticity is positive: $\eta > 0$. If the supply curve slopes downward, the supply elasticity is negative: $\eta < 0$.

To show how to calculate the elasticity of supply, we use the supply function for pork (based on Moschini and Meilke, 1992), Equation 2.7,

$$Q = 88 + 40p,$$

where Q is the quantity of pork supplied in million kg per year and p is the price of pork in dollars per kg. This supply function is a straight line in Figure 3.4. (The horizontal axis starts at 176 rather than at the origin.) The number multiplied by p in the supply function, 40, shows how much the quantity supplied rises as the price increases: $\Delta Q/\Delta p = 40$. At the equilibrium where $p = \$3.30$ and $Q = 220$, the elasticity of supply of pork is

$$\eta = \frac{\Delta Q}{\Delta p}\frac{p}{Q} = 40 \times \frac{3.30}{220} = 0.6.$$

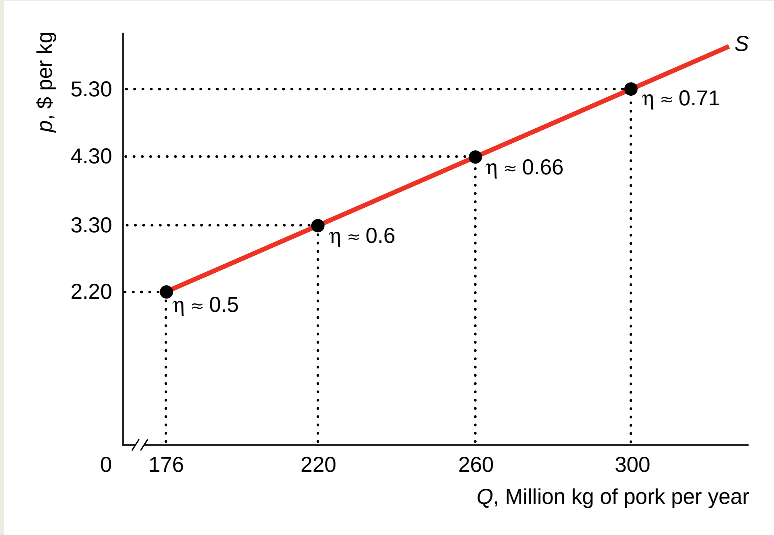

Figure 3.4 Elasticity Along the Pork Supply Curve. The elasticity of supply, η, varies along the pork supply curve. The higher the price, the larger is the supply elasticity.

As the price of pork increases by 1%, the quantity supplied rises by slightly less than two-thirds of a percent.

We use the terms *inelastic* and *elastic* to describe *upward-sloping* supply curves, just as we did for demand curves. If $\eta = 0$, we say that the supply curve is *perfectly inelastic*: The supply does not change as price rises. If $0 < \eta < 1$, the supply curve is *inelastic* (but not perfectly inelastic): A 1% increase in price causes a less than 1% rise in the quantity supplied. If $\eta = 1$, the supply curve has a *unitary elasticity*: A 1% increase in price causes a 1% increase in quantity. If $\eta > 1$, the supply curve is *elastic*. If η is infinite, the supply curve is *perfectly elastic*.

Elasticity Along the Supply Curve

The elasticity of supply may vary along the supply curve. The elasticity of supply varies along most linear supply curves.

The supply function of a linear supply curve is

$$Q = g + hp,$$

where g and h are constants. By the same reasoning as before, $\Delta Q = h\Delta p$, so $h = \Delta Q/\Delta p$ shows the change in the quantity supplied as price changes.

The supply curve for pork is $Q = 88 + 40p$, so $g = 88$ and $h = 40$. Because $h = 40$ is positive, the quantity of pork supplied increases as the price of pork rises.

The elasticity of supply for a linear supply function is $\eta = h(p/Q)$. The elasticity of supply for the pork is $\eta = 40p/Q$. As the ratio p/Q rises, the supply elasticity rises. Along most linear supply curves, the ratio p/Q changes as p rises.

The pork supply curve, Figure 3.4, is inelastic at each point shown. The elasticity of supply varies along the pork supply curve: It is 0.5 when p = \$2.20, 0.6 when p = \$3.30, and about 0.71 when p = \$5.30.

Only *constant elasticity of supply curves* have the same elasticity at every point along the curve.[7] Two extreme examples of both constant elasticity of supply curves and linear supply curves are the vertical and the horizontal supply curves.

The supply curve that is vertical at a quantity, Q^*, is perfectly inelastic. No matter what the price is, firms supply Q^*. An example of inelastic supply is a perishable item such as fresh fruit. If the perishable good is not sold, it quickly becomes worthless. Thus the seller accepts any market price for the good.

A supply curve that is horizontal at a price, p^*, is perfectly elastic. Firms supply as much as the market wants—a potentially unlimited amount—if the price is p^* or above. Firms supply nothing at a price below p^*, which does not cover their cost of production.

3.4 LONG RUN VERSUS SHORT RUN

The shapes of demand and supply curves depend on the relevant time period. Short-run elasticities may differ substantially from long-run elasticities. The duration of the *short run* depends on how long it takes consumers or firms to adjust for a particular good.

Demand Elasticities over Time

Two factors that determine whether short-run demand elasticities are larger or smaller than long-run elasticities are ease of substitution and storage opportunities. Often one can substitute between products in the long run but not in the short run.

When oil prices rose rapidly in the 1970s and 1980s because of actions by OPEC, consumers in most Western countries did not greatly alter the amount of oil they demanded. Someone who drove 27 miles to and from work every day in a 1969 Chevy could not easily reduce the amount of gasoline purchased. In the long run, however, this person could buy a smaller car, get a job closer to home, join a car pool, or in other ways reduce the amount of gasoline purchased.

Gallini (1983) estimated long-run demand elasticities that are more elastic than the short-run elasticity for gasoline in Canada. She found that the short-run elasticity is –0.35; the 5-year intermediate-run elasticity is nearly twice as elastic, –0.7; and the 10-year, long-run elasticity is approximately –0.8, which is slightly more elastic. Thus a 1% increase in price lowers the quantity demanded by only about a 0.35% in the short run but by more than twice as much, 0.8%, in the long run. Similarly, Grossman and Chaloupka (1998) estimate that a rise in the street price of cocaine has a larger long-run than short-run effect on cocaine consumption by young adults (aged 17–29). The long-run demand elasticity is –1.35, whereas the short-run elasticity is –0.96.

[7]All constant elasticity of supply curves are of the form $Q = Bp^{\eta}$, where B is a constant and η is the constant elasticity of supply at every point along the curve.

For goods that can be stored easily, short-run demand curves may be more elastic than long-run curves. If frozen orange juice goes on sale this week at your local supermarket, you may buy large quantities and store the extra in your freezer. As a result, you may be more sensitive to price changes for frozen orange juice in the short run than in the long run.

Supply Elasticities over Time

Supply curves too may have different elasticities in the short run than in the long run. If a manufacturing firm wants to increase production in the short run, it can do so by hiring workers to use its machines around the clock, but how much it can expand its output is limited by the fixed size of its manufacturing plant and the number of machines it has. In the long run, however, the firm can build another plant and buy or build more equipment. Thus we would expect this firm's long-run supply elasticity to be greater than its short-run elasticity.

Similarly, Adelaja (1991) found that the short-run elasticity of supply of milk is 0.36, whereas the long-run supply elasticity is 0.51. Thus, the long-run quantity response to a 1% increase in price is about 42% (= [0.51 – 0.36]/0.36) more than in the short run.

3.5 EFFECTS OF A SALES TAX

Before voting for a new sales tax, legislators want to predict the effect of the tax on prices, quantities, and tax revenues. If the new tax will produce a large increase in the price, legislators who vote for the tax may lose their jobs in the next election. Voters' ire is likely to be even greater if the tax does not raise significant tax revenues.

In this section, we examine three questions about the effects of a sales tax:

1. What effect does a sales tax have on equilibrium prices and quantity?
2. Is it true, as many people claim, that taxes assessed on producers are *passed along* to consumers? That is, do consumers pay for the entire tax?
3. Do the equilibrium price and quantity depend on whether the tax is assessed on consumers or on producers?

How much a tax affects the equilibrium price and quantity and how much of the tax falls on consumers depend on the shape of the demand and supply curves, which is summarized by the elasticities. Knowing only the elasticities of demand and supply, we can make accurate predictions about the effects of a new tax and determine how much of the tax falls on consumers.

Two Types of Sales Taxes

Governments use two types of sales taxes. The most common sales tax is called an *ad valorem* tax by economists and *the* sales tax by real people. For every dollar the consumer spends, the government keeps a fraction, α, which is the *ad valorem* tax rate. Since 1997, Japan's national sales tax has been α = 5%. If a Japanese consumer buys a CD player for \$100, the government collects $\alpha \times \$100 = 5\% \times \$100 = \$5$ in taxes, and the seller receives $(1 - \alpha) \times \$100 = \$95$.[8]

The other type of sales tax is a *specific* or *unit* tax, where a specified dollar amount, τ, is collected per unit of output. The federal government collects $\tau = 18.4¢$ on each gallon of gas sold in the United States. Many communities charge a fixed filing fee or tax on every house sold.

Equilibrium Effects of a Specific Tax

To answer our three questions, we must extend the standard supply-and-demand analysis to take taxes into account. Let's start by assuming that the specific tax is assessed on firms at the time of sale. If the consumer pays p for a good, the government takes τ and the seller receives $p - \tau$.

Specific Tax Effects in the Pork Market. Suppose that the government collects a specific tax of $\tau = \$1.05$ per kg of processed pork from pork producers. Because of the tax, suppliers keep only $p - \tau$ of price p that consumers pay. Thus at every possible price paid by consumers, firms are willing to supply less than when they received the full amount consumers paid. Before the tax, firms were willing to supply 206 million kg per year at a price of \$2.95 as the pretax supply curve S^1 in Figure 3.5 shows. After the tax, firms receive only \$1.90 if consumers pay \$2.95, so they are not willing to supply 206. For firms to be willing to supply 206, they must receive \$2.95 after the tax, so consumers must pay \$4. As a result, the after-tax supply curve, S^2, is $\tau = \$1.05$ above the original supply curve S^1 at every quantity, as the figure shows.

We can use this figure to illustrate the answer to our first question concerning the effects of the tax on the equilibrium. *The specific tax causes the equilibrium price consumers pay to rise*, *the equilibrium quantity to fall, and tax revenue to rise.*

The intersection of the pretax pork supply curve S^1 and the pork demand curve D in Figure 3.5 determines the pretax equilibrium, e_1. The equilibrium price is $p_1 = \$3.30$, and the equilibrium quantity is $Q_1 = 220$. The tax shifts the supply curve to S^2, so the after-tax equilibrium is e_2, where consumers pay $p_2 = \$4$, firms receive $p_2 - \$1.05 = \$2.95$, and $Q_2 = 206$. Thus the tax causes the price that consumers pay to increase ($\Delta p = p_2 - p_1 = \$4 - \$3.30 = 70¢$) and the quantity to fall ($\Delta Q = Q_2 - Q_1 = 206 - 220 = -14$).

Although the consumers and producers are worse off because of the tax, the government acquires new tax revenue of $T = \tau Q = \$1.05$ per kg $\times$ 206 million kg per year = \$216.3 million per year. The length of the shaded rectangle in the figure is $Q_2 = 206$ million kg per year, and its height is $\tau = \$1.05$ per kg, so the area of the rectangle equals the tax revenue. (The figure shows only part of the length of the rectangle because the horizontal axis starts at 176.)

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[8]For specificity, we assume that the price firms receive is $p = (1 - \alpha)p^*$, where p^* is the price consumers pay and α is the ad valorem tax rate on the price consumers pay. Many governments, however, set the ad valorem sales tax, β, as an amount added to the price sellers charge, so consumers pay $p^* = (1 + \beta)p$. By setting α and β appropriately, the taxes are equivalent. Here $p = p^*/(1 + \beta)$, so $(1 - \alpha) = 1/(1 + \beta)$. For example, if $\beta = \frac{1}{3}$, then $\alpha = \frac{1}{4}$.

How Specific Tax Effects Depend on Elasticities. The effects of the tax on the equilibrium prices and quantity depend on the elasticities of supply and demand. The government raises the tax from zero to τ, so the change in the tax is $\Delta\tau = \tau - 0 = \tau$. In response to this change in the tax, the price consumers pay increases by

$$\Delta p = \left(\frac{\eta}{\eta - \varepsilon}\right)\Delta\tau, \tag{3.6}$$

where ε is the demand elasticity and η is the supply elasticity at the equilibrium (this equation is derived in Appendix 3A). The demand elasticity for pork is $\varepsilon = -0.3$, and the supply elasticity is $\eta = 0.6$, so a change in the tax of $\Delta\tau = \$1.05$ causes the price consumers pay to rise by

$$\Delta p = \left(\frac{\eta}{\eta - \varepsilon}\right)\Delta\tau = \frac{0.6}{0.6 - [-0.3]} \times \$1.05 = 70¢,$$

as Figure 3.5 shows.

For a given supply elasticity, the more elastic demand is, the less the equilibrium price rises when a tax is imposed. In the pork equilibrium in which the supply elasticity is $\eta = 0.6$, if the demand elasticity were $\varepsilon = -2.4$ instead of -0.3 (that is, the

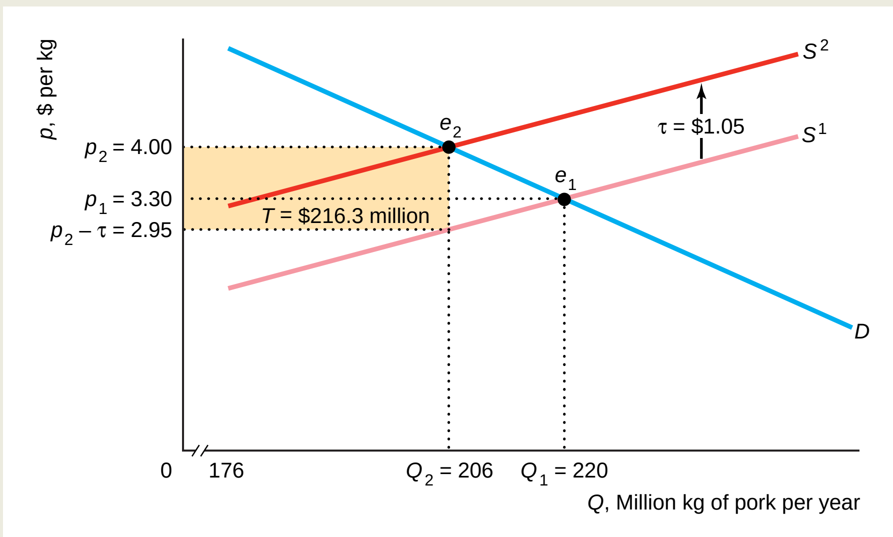


Figure 3.5 Effect of a \$1.05 Specific Tax on the Pork Market Collected from Producers. The specific tax of $\tau = \$1.05$ per kg collected from producers shifts the pretax pork supply curve from S^1 to the posttax supply curve, S^2. The tax causes the equilibrium to shift from e_1 (determined by the intersection of S^1 and D) to e_2 (intersection of S^2 with D). The equilibrium price increases from \$3.30 to \$4.00. Two-thirds of the incidence of the tax falls on consumers, who spend 70¢ more per unit. Producers receive 35¢ less per unit after the tax. The government collects tax revenues of $T = \tau Q_2 = \$216.3$ million per year.

linear demand curve had a less steep slope through the original equilibrium point), the consumer price would rise only $0.6/(0.6 - [-2.4]) \times \$1.05 = 21¢$ instead of 70¢.

Similarly, for a given demand elasticity, the greater the supply elasticity, the larger the increase in the equilibrium price consumers pay when a tax is imposed. In the pork example, in which the demand elasticity is $\varepsilon = -0.3$, if the supply elasticity were $\eta = 1.2$ instead of 0.6, the consumer price would rise $1.2/(1.2 - [-0.3]) \times \$1.05 = 84¢$ instead of 70¢.

Application

DISCOURAGING SMOKING

If the government really wants to stop people—especially teenagers—from smoking, how should it do so? It could spend millions on education programs and public service ads. Alternatively, the government could raise the tax on cigarettes, which would reduce smoking and raise revenues rather than cost money.

The more elastic the demand, the more a tax on cigarettes discourages smoking. Several economic studies estimate that a 10% increase in the real price of cigarettes lowers overall U.S. cigarette consumption by 3% to 6% and reduces the number of children smoking by about 6% to 7%.

When the price of cigarettes in Canada increased 158% from 1979 to 1991 (after adjusting for inflation and including taxes), teenage smoking dropped by 61% and overall smoking by 38%. Thus, a moderate tax that raises the price of cigarettes can reduce smoking significantly.

In 2002, the Canadian federal tax rose to $1.035 per pack of cigarettes, and the Canadian provinces impose additional taxes. The U.S. federal cigarette tax is only 39¢, but the median state tax is 48¢. The tax per pack averaged 8.2¢ in major tobacco states (2.5¢ in Virginia and 5¢ in North Carolina) and 65.5¢ in other states, ranging up to $1.425 in Washington; $1.50 in New Jersey and New York (New York City heaps on another $1.50); and $1.51 in Massachusetts.

Because of this difference in rates across jurisdictions, a tax increase in one may not lead to a substantial price increase for all consumers in that jurisdiction because of common practices like illegal smuggling and online buying. The

European Commission has accused Philip Morris and R.J. Reynolds with cigarette smuggling in Europe. R.J. Reynolds's Canadian affiliate Northern Brands and its former president pleaded guilty to illegally smuggling cigarettes from the United States into Canada. When Michigan raised its cigarette tax from 25¢ to 75¢ in 1994, taxable cigarette sales fell nearly 27%, while sales over the Indiana border, where the tax is 15.5¢, jumped 40%. As a consequence, if one wants to discourage smoking in a given state, a national tax is more effective than high taxes in that state alone. Moreover, states are losing millions of tax dollars as people buy cigarettes from online vendors, 78% of which ignore a federal law requiring them to report sales to local regulators who can then dun purchasers for taxes.

However, smuggling and tax avoidance do not always surface as major problems. A survey in California found that after the state raised its tax by 50¢ a pack in 1999, no more than 5% of all smokers purchased cigarettes from nearby states, Mexico, Indian reservations, military bases, or via the Internet. Six months after this tax was instituted, per capita cigarette consumption decreased by 30% in California.

Cigarette smoking in the United States would be greatly reduced if U.S. federal cigarette taxes were higher. In addition to the direct effect of higher federal taxes, Besley and Rosen (1998) find that a 10¢ increase in the federal tax on a pack of cigarettes leads to an average 2.8¢ increase in state cigarette taxes.

The U.S. tax burden on cigarettes is the lowest of all industrialized countries. As of 1999, the U.S. tax per pack averaged 66¢ across the states. The average in Canada was \$1.97, ranging from \$1.12 to \$2.97. Taxes in other countries were \$1.76 in Hong Kong, \$2.76 in New Zealand, \$2.92 in Australia, \$3.13 in Sweden, \$4.02 in Denmark, \$4.16 in Ireland, \$4.30 in the United Kingdom, and \$5.23 in Norway. Adjusting for inflation, the U.S. federal tax is currently only about half its level two decades ago.

Tax Incidence of a Specific Tax

We can now answer our second question: Who is hurt by the tax? The **incidence of a tax on consumers** is the share of the tax that falls on consumers. The incidence of the tax that falls on consumers is $\Delta p/\Delta \tau$, the amount by which the price to consumers rises as a fraction of the amount the tax increases.

In our pork example in Figure 3.5, a $\Delta \tau = \$1.05$ increase in the specific tax causes consumers to pay $\Delta p = 70¢$ more per kg than they would if no tax were assessed. Thus consumers bear two-thirds of the incidence of the pork tax:

$$\frac{\Delta p}{\Delta \tau} = \frac{\$0.70}{\$1.05} = \frac{2}{3}.$$

Firms receive $(p_2 - \tau) - p_1 = (\$4 - \$1.05) - \$3.30 = \$2.95 - \$3.30 = -35¢$ less per kg than they would in the absence of the tax. The incidence of the tax on firms—the amount by which the price to them falls, divided by the tax—is $\$0.35/\$1.05 = \frac{1}{3}$. The sum of the share of the tax on consumers, $\frac{2}{3}$, and that on firms, $\frac{1}{3}$, adds to the entire tax effect, 1. Equivalently, the increase in price to consumers minus the drop in price to firms equals the tax: 70¢ – (–35¢) = \$1.05 = τ.

How Tax Incidence Depends on Elasticities. If the demand curve slopes downward and the supply curve slopes upward, as in Figure 3.5, the incidence of the tax *does not* fall solely on consumers. Firms do not pass along the entire tax in higher prices.

Firms can pass along the full cost of the tax only when the demand or supply elasticities take on certain extreme values. To determine the conditions under which firms can pass along the full tax, we need to know how the incidence of the tax depends on the elasticities of demand and supply at the pretax equilibrium. By dividing both sides of Equation 3.6 by $\Delta\tau$, we can write the incidence of the tax that falls on consumers as

$$\frac{\Delta p}{\Delta \tau} = \frac{\eta}{\eta - \varepsilon}. \tag{3.7}$$

Because the demand elasticity for pork is $\varepsilon = -0.3$ and the supply elasticity is $\eta = 0.6$, the incidence of the pork tax that falls on consumers is

$$\frac{0.6}{0.6 - (-0.3)} = \frac{2}{3}.$$

The more elastic the demand at the equilibrium, holding the supply elasticity constant, the lower the burden of the tax on consumers. Similarly, the greater the supply elasticity, holding the demand elasticity constant, the greater the burden on consumers. Thus as the demand curve becomes relatively inelastic (ε approaches zero) or the supply curve becomes relatively elastic (η becomes very large), the incidence of the tax falls mainly on consumers.

Solved Problem 3.1

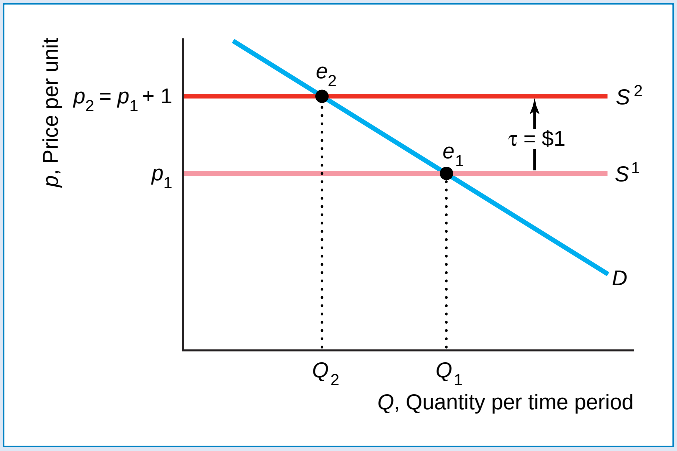
If the supply curve is perfectly elastic and demand is linear and downward sloping, what is the effect of a \$1 specific tax collected from producers on equilibrium price and quantity, and what is the incidence on consumers? Why?

Answer

1. *Determine the equilibrium in the absence of a tax:* Before the tax, the perfectly elastic supply curve, S^1 in the graph, is horizontal at p_1. The downward-sloping linear demand curve, D, intersects S^1 at the pretax equilibrium, e_1, where the price is p_1 and the quantity is Q_1.
2. *Show how the tax shifts the supply curve and determine the new equilibrium:* A specific tax of \$1 shifts the pretax supply curve upward by \$1 to S^2, which is horizontal at $p_1 + 1$. The intersection of D and S^2 determines the after-tax equilibrium, e_2, where the price consumers pay is $p_2 = p_1 + 1$, the price firms receive is $p_2 - 1 = p_1$, and the quantity is Q_2.

3. *Compare the before- and after-tax equilibria:* The specific tax causes the equilibrium quantity to fall from Q_1 to Q_2, the price firms receive to remain at p_1, and the equilibrium price consumers pay to rise from p_1 to $p_2 = p_1 + 1$. The entire incidence of the tax falls on consumers:

$$\frac{\Delta p}{\Delta \tau} = \frac{p_2 - p_1}{\$1} = \frac{\$1}{\$1} = 1.$$



4. *Explain why:* The reason consumers must absorb the entire tax is that firms will not supply the good at a price that is any lower than they received before the tax, p_1. Thus the price must rise enough that the price suppliers receive after tax is unchanged. As consumers do not want to consume as much at a higher price, the equilibrium quantity falls.

Elasticity, Revenue, and Tax Strategy. Governments often use a sales tax to raise tax revenue. However, such a tax harms consumers and producers by reducing the equilibrium quantity.

Some economists and politicians argue that, all else the same, we should tax goods with relatively inelastic demands more heavily. They argue that the less elastic demand is, the less harm a sales tax does in terms of reduced consumption and the more revenue it raises (see Problem 21 at the end of the chapter). If the demand curve is vertical at Q_1, the quantity demanded is unchanged by a tax τ, and the revenue is τQ_1. With a downward-sloping demand curve (as in Figure 3.5), the tax reduces the quantity demanded from the original quantity Q_1 to Q_2, and the tax is only τQ_2, which is less than τQ_1.

Presumably, most voters would agree with the goal of reducing the harm of taxes. Whether they favor increasing tax revenues is less clear. Moreover, the less elastic the demand, the larger the incidence of the tax that consumers bear.

Application

GASOLINE TAXES AS A REVENUE SOURCE

Many governments rely heavily on gasoline taxes for revenues. Because the demand for gasoline is relatively inelastic, a tax on gasoline falls mainly on consumers and has little effect on the equilibrium quantity of gasoline consumed.

Gallini (1983) estimates that the short-run demand elasticity for gasoline in Canada is about –0.35. Another study concludes that the elasticity in Europe is about –0.2. Umberto Rastelli, an economist in the Italian Foreign Ministry, observed, "When the tax goes up again, we can measure a little reduction in traffic for a couple of weeks—but after that, it's back to normal." Because of this relatively inelastic demand, most developed countries (except the United States) apply very large specific taxes to gasoline to raise substantial revenues.

U.S. and Canadaian gasoline taxes are the lowest in the industrialized world. As of 2002, the U.S. federal gasoline tax was 18.4¢ per gallon, and average state and local taxes raised the total tax to 38.2¢ per gallon, which is 28% of the price consumers pay. The U.S. federal government raises less than 1% of its final budget from the gas tax. Canadians pay a tax of 73.4¢ per gallon, which is 43% of the final price.

Other industrial nations set much higher gasoline taxes. Japan's $1.81 tax per gallon raises 5% of government revenues. European taxes per gallon average 20 times U.S. federal rates. The U.K. tax is $3.19 per gallon, which is 77% of the $4.18 per gallon consumers pay. This tax produces 17% of the government's budget revenues. Taxes are almost as high in Italy ($2.60), France ($2.68), and Germany ($2.79), where these taxes raise 4% to 5% of the national budget revenues.

The United States could raise substantially more revenues by increasing its gasoline tax. It is estimated that each extra 1¢ per gallon in gasoline tax yields an extra $1 billion in revenues. A 50¢ per gallon increase in the tax would cost the typical American household between $500 and $1,200 a year.

The Same Equilibrium No Matter Who Is Taxed

Our third question is "Does the equilibrium or the incidence of the tax depend on whether the tax is collected from suppliers or demanders?" Surprisingly, in the supply-and-demand model, the equilibrium and the incidence of the tax are the same regardless of whether the government collects the tax from consumers or producers.

We've already seen that firms are able to pass on some or all of the tax collected from them to consumers. We now show that, if the tax is collected from consumers, they can pass the producer's share back to the firms.

Suppose the specific tax $\tau = \$1.05$ on pork is collected from consumers rather than from sellers. Because the government takes τ from each p consumers spend, sellers receive only $p - \tau$. Thus the demand curve as seen by firms shifts downward by $1.05 from D^1 to D^2 in Figure 3.6.

The intersection of D^2 and the supply curve S determines the after-tax equilibrium, e_2, where the equilibrium quantity is Q_2 and the price received by producers

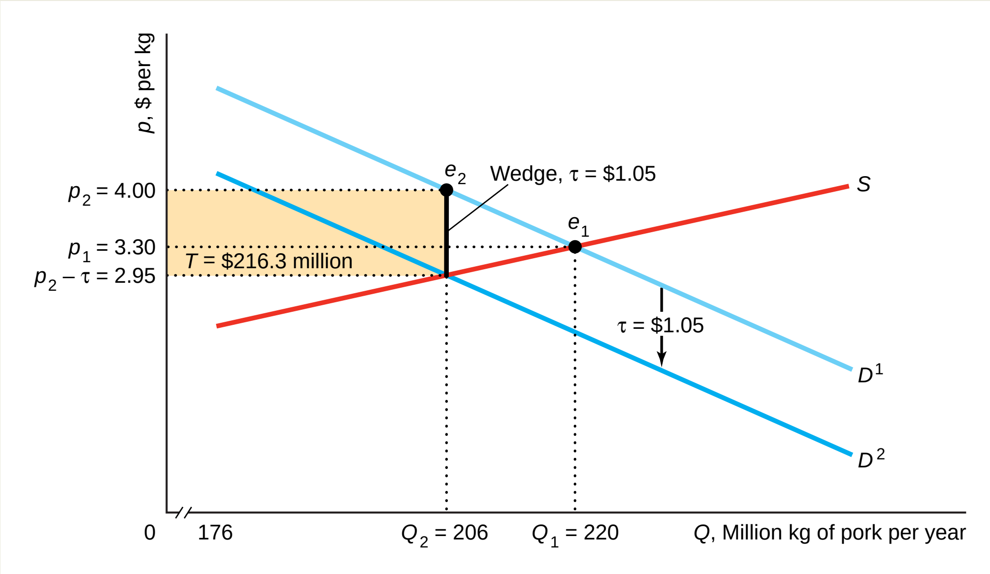


Figure 3.6 Effect of a $1.05 Specific Tax on Pork Collected from Consumers. The tax shifts the demand curve down by τ = $1.05 from D^1 to D^2. The new equilibrium is the same as when the tax is applied to suppliers in Figure 3.5. We can also determine the after-tax equilibrium by sticking a wedge with length τ = $1.05 between S and D^1.

is $p_2 - \tau$. The price paid by consumers, p_2 (on the original demand curve D^1 at Q_2), is τ above the price received by producers.

Comparing Figure 3.6 to Figure 3.5, we see that the after-tax equilibrium is the same regardless of whether the tax is imposed on the consumers or the sellers. The price to consumers rises by the same amount, Δp, so the incidence of the tax, $\Delta p/\Delta\tau$, is also the same.

A specific tax, regardless of whether the tax is collected from consumers or producers, creates a *wedge* equal to the per-unit tax of τ between the price consumers pay, p, and the price suppliers receive, $p - \tau$. Indeed, we can insert a wedge—the vertical line labeled τ = $1.05 in the figure—between the original supply and demand curves to determine the after-tax equilibrium.

In short, regardless of whether firms or consumers pay the tax to the government, you can solve tax problems by shifting the supply curve, shifting the demand curve, or using a wedge. All three approaches give the same answer.

The Similar Effects of *Ad Valorem* and Specific Taxes

In contrast to specific sales taxes, governments levy *ad valorem* taxes on a wide variety of goods. Most states apply an *ad valorem* sales tax to most goods and services, exempting only a few staples such as food and medicine. There are 6,400 different *ad valorem* sales tax rates across the United States, which can go as high as 8.5% (Besley and Rosen, 1999).

Suppose that the government imposes an *ad valorem* tax of α, instead of a specific tax, on the price that consumers pay for processed pork. We already know that the equilibrium price is \$4 with a specific tax of \$1.05 per kg. At that price, an *ad valorem* tax of α = \$1.05/\$4 = 26.25% raises the same amount of tax per unit as a \$1.05 specific tax.

It is usually easiest to analyze the effects of an *ad valorem* tax by shifting the demand curve. Figure 3.7 shows how a specific tax and an *ad valorem* tax shift the processed pork demand curve. The specific tax shifts the pretax demand curve, D, down to D^s, which is parallel to the original curve. The *ad valorem* tax shifts the demand curve to D^a. At any given price p, the gap between D and D^a is αp, which is greater at high prices than at low prices. The gap is \$1.05 (= 0.2625 × \$4) per unit when the price is \$4, and \$2.10 when the price is \$8.

Imposing an *ad valorem* tax causes the after-tax equilibrium quantity, Q_2, to fall below the original quantity, Q_1, and the after-tax price, p_2, to rise above the original price, p_1. The tax collected per unit of output is $\tau = \alpha p_2$. The incidence of the tax that falls on consumers is the change in price, $\Delta p = (p_2 - p_1)$, divided by the change in the per unit tax, $\Delta t = \alpha p_2 - 0$, collected, $\Delta p/(\alpha p_2)$. The incidence of an *ad valorem* tax is generally shared between consumers and suppliers. Because the *ad valorem* tax of α = 26.25% has exactly the same impact on the equilibrium pork price and raises the same amount of tax per unit as the \$1.05 specific tax, the

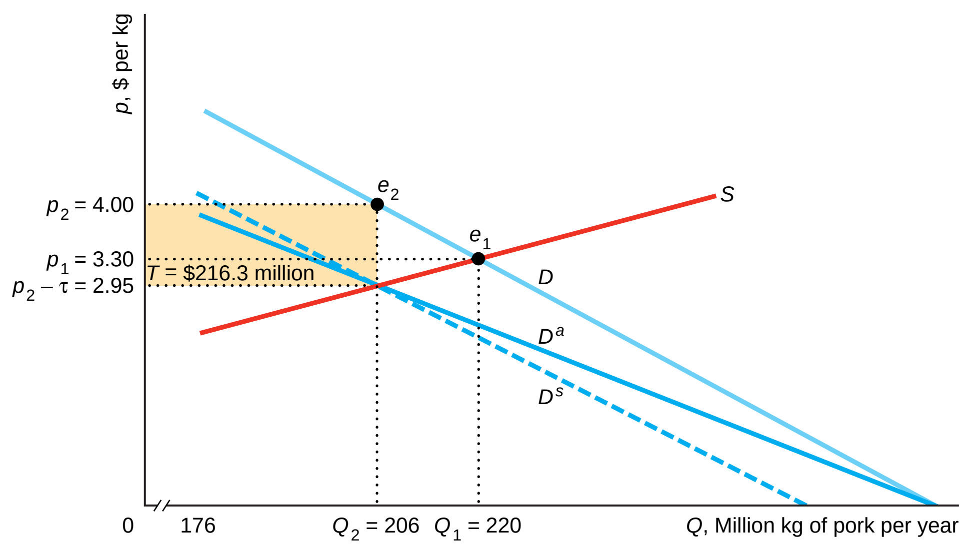


Figure 3.7 Comparison of an *Ad Valorem* and a Specific Tax on Pork. Without a tax, the demand curve is D and the supply curve is S. The *ad valorem* tax of α = 26.25% shifts the demand curve facing firms to D^a. The gap between D and D^a, the per-unit tax, is larger at higher prices. In contrast, the demand curve facing firms given a specific tax of \$1.05 per kg, D^s, is parallel to D. The after-tax equilibrium is the same with both of these taxes.

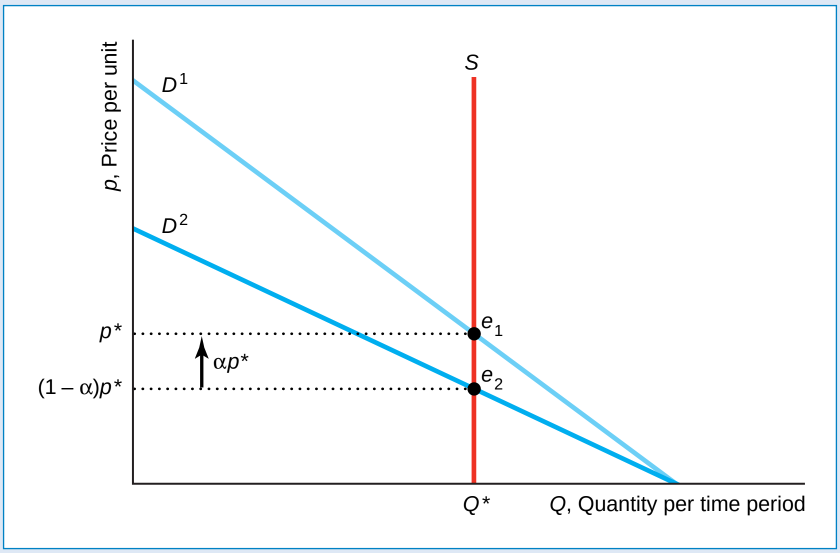
incidence is the same for both types of taxes. (As with specific taxes, the incidence of the *ad valorem* tax depends on the elasticities of supply and demand, but we'll spare you going through that.)

Solved Problem 3.2

If the short-run supply curve for fresh fruit is perfectly inelastic and the demand curve is a downward-sloping straight line, what is the effect of an ad valorem tax on equilibrium price and quantity, and what is the incidence on consumers? Why?

Answer

1. *Determine the before-tax equilibrium:* The perfectly inelastic supply curve, S, is vertical at Q^* in the graph. The pretax demand curve, D^1, intersects S at e_1, where the equilibrium price to both consumers and producers is p^* and the equilibrium quantity is Q^*.



2. *Show how the tax shifts the demand curve, and determine the after-tax equilibrium:* When the government imposes an ad valorem tax with a rate of α, the demand curve as seen by the firms rotates down to D^2, where the gap between the two demand curves is αp. The intersection of S and D^2 determines the after-tax equilibrium, e_2. The equilibrium quantity remains unchanged at Q^*. Consumers continue to pay p^*. The government collects αp^* per unit, so firms receive less, $(1 - \alpha)p^*$, than the p^* they received before the tax.

3. *Determine the incidence of the tax on consumers:* The consumers continue to pay the same price, so $\Delta p = 0$ when the tax increases by αp^* (from 0), and the incidence of the tax that falls on consumers is $\$0/(\alpha p^*) = 0\%$.

4. Explain why the incidence of the tax falls entirely on firms: The reason why firms absorb the entire tax is that firms supply the same amount of fruit, Q*, no matter what tax the government sets. If firms were to raise the price, consumers would buy less fruit and suppliers would be stuck with the essentially worthless excess quantity, which would spoil quickly. Thus because suppliers prefer to sell their produce at a positive price rather than a zero price, they absorb any tax-induced drop in price.

Application

INCIDENCE OF FEDERAL *AD VALOREM* TAXES

Thanks to a change in federal law, we have a natural experiment that determines in which markets consumers bear the full incidence of sales taxes. On July 1, 1965, the federal *ad valorem* taxes on many goods and services were eliminated, and the 10% tax on automobiles was reduced to 7%. By the end of 1965, taxes on admissions to theaters, variety shows, and athletic and racing events, as well as on club dues and initiation fees, were also canceled.

Comparing prices before and after this change, we can determine how much the price fell in response to the tax's elimination. When the tax was in place, the tax per unit on a good that sold for p was αp. If the price fell by αp when the tax was eliminated, consumers must have been bearing the full incidence of the tax. Consequently, consumers got the full benefit of removing the tax from those goods.

Brownlee and Perry (1967) found that the entire amount of the tax cut was passed on to consumers immediately for many commodities. These commodities and services included all those studied for which the taxes were collected at the retail level (except admissions and club dues) and most commodities for which excise taxes were imposed at the manufacturer level. Goods for which consumers got essentially the entire tax cut included face powder, sterling silverware, wristwatches, and handbags. When the supply curve is nearly perfectly elastic, we would expect the full incidence of a tax—and hence the full benefit of the tax cut—to fall on consumers (as in Solved Problem 3.1). A perfectly elastic supply curve is likely when all firms have the same costs, as we might expect in retailing. The full incidence of the tax also falls on consumers if the demand curve is completely inelastic (end-of-chapter Question 6).

Essentially none of the tax savings were passed on for motion picture admissions and club dues. We would expect this result either if the elasticity of demand were perfectly elastic (Question 7 at the end of this chapter) or if the elasticity of supply were perfectly inelastic (Question 8 at the end of the chapter).

The price decline was less than the amount of the tax cut for many lower-valued items on which manufacturers' taxes were reduced. The 10% reduction in taxes led to only a 6.3% drop in prices for portable TVs, 1.4% for golf clubs, and 0.9% for stereo records and golf balls. Thus for these goods, neither the demand curves nor the supply curves were perfectly elastic or perfectly inelastic.

Summary

1. **How shapes of the demand and supply curves matter:** The degree to which a shock (such as an increase in the price of a factor) shifts the supply curve and affects the equilibrium price and quantity depends on the shape of the demand curve. Similarly, the degree to which a shock (such as an increase in the price of a substitute) shifts the demand curve and affects the equilibrium depends on the shape of the supply curve.
2. **Sensitivity of quantity demanded to price:** The price elasticity of demand (or elasticity of demand), ε, summarizes the shape of a demand curve at a particular point. The elasticity of demand is the percentage change in the quantity demanded in response to a given percentage change in price. For example, a 1% increase in price causes the quantity demanded to fall by ε%. Because demand curves slope downward according to the Law of Demand, the elasticity of demand is always negative.

   The demand curve is perfectly inelastic if $\varepsilon = 0$, inelastic if $0 > \varepsilon > -1$, unitary elastic if $\varepsilon = -1$, elastic if $\varepsilon < -1$, and perfectly elastic when ε approaches negative infinity. A vertical demand curve is perfectly inelastic at every price. A horizontal demand curve is perfectly elastic.

   The income elasticity of demand is the percentage change in the quantity demanded in response to a given percentage change in income. The cross-price elasticity of demand is the percentage change in the quantity demanded of one good when the price of a related good increases by a given percentage.
3. **Sensitivity of quantity supplied to price:** The price elasticity of supply (or elasticity of supply), η, is the percentage change in the quantity supplied in response to a given percentage change in price. The elasticity of supply is positive if the supply curve has an upward slope. A vertical supply curve is perfectly inelastic. A horizontal supply curve is perfectly elastic.
4. **Long run versus short run:** Long-run elasticities of demand and supply may differ from the corresponding short-run elasticities. Where consumers can substitute between goods more readily in the long run, long-run demand curves are more elastic than short-run demand curves. However, if goods can be stored easily, short-run demand curves are more elastic than long-run curves. If producers can increase output at lower extra cost in the long run than in the short run, the long-run elasticity of supply is greater than the short-run elasticity.
5. **Effects of a sales tax:** The two common types of sales taxes are *ad valorem* taxes, by which the government collects a fixed percent of the price paid per unit, and specific taxes, by which the government collects a fixed amount of money per unit sold. Both types of sales taxes typically raise the equilibrium price and lower the equilibrium quantity. Both usually raise the price consumers pay and lower the price suppliers receive, so consumers do not bear the full burden or incidence of the tax. The effects on quantity, price, and the incidence of the tax that falls on consumers depend on the demand and supply elasticities. In competitive markets, for which supply-and-demand analysis is appropriate, the effect of a tax on equilibrium quantities, prices, and the incidence of the tax is unaffected by whether the tax is collected from consumers or producers.

Questions

QUIZ

1. If a 2% increase in the price of flame throwers results in a 3% decline in the quantity demanded, what is the elasticity of demand for flame throwers?
2. What section of a straight-line demand curve is elastic?
3. Give some examples of evidence that would convince you that the demand curve for a given product was inelastic. Similarly, what evidence would convince you that a supply curve was elastic? (*Hint*: Consider shocks caused by changes in factors that affect demand or by taxes.)
4. In 1997, the shares of consumers who had cable television service was 59% for people with incomes of \$25,000 or less; 66%, \$25,000–\$34,999; 67%, \$35,000–\$49,999; 71%, \$50,000–\$74,999; and 78%, \$75,000 or more.

What can you say about the income elasticity for cable television?

5. A rent control law limits the price of an apartment. What is the likely effect of such a law in the short run? What is the likely effect of the law in the long run? Be sure to discuss the quantity and quality of apartments available for rent.
6. What is the effect of a \$1 specific tax on equilibrium price and quantity if demand is perfectly inelastic? What is the incidence on consumers? Explain.
7. What is the effect of a \$1 specific tax on equilibrium price and quantity if demand is perfectly elastic? What is the incidence on consumers? Explain.
8. What is the effect of a \$1 specific tax on equilibrium price and quantity if supply is perfectly inelastic? What is the incidence on consumers? Explain.
9. What is the effect of a \$1 specific tax on equilibrium price and quantity if demand is perfectly elastic and supply is perfectly inelastic? What is the incidence on consumers? Explain.
10. List as many conditions as you can for the incidence of a tax to fall entirely on consumers.
11. Do you care whether a 15¢ tax per gallon of milk is collected from milk producers or from consumers at the store? Why?
12. California supplies the United States with 80% of its eating oranges. In late 1998, four days of freezing temperatures in the state's Central Valley substantially damaged the orange crop. In early 1999, Food Lion, with 1,208 grocery stores mostly in the Southeast, said its prices for fresh oranges would rise by 20% to 30%, which was less than the 100% increase it had to pay for the oranges. Explain why the price to consumers did not rise by the full amount of Food Lion's price increase. What can you conclude about the elasticities of demand and supply for oranges? (*Hint:* Remember what determines the incidence of a tax.)
13. Consider the market for labor services. The state collects a tax of α (where $0 < \alpha < 1$) cents of every dollar a worker earns. If the state raises its minimum wage, what happens to the amount of tax revenues it collects? Must tax revenue necessarily rise or fall?
14. Traditionally, the perfectly round, white saltwater pearls from oysters have been prized above small, irregularly shaped, and strangely colored freshwater pearls from mussels. By 2002, scientists in China (where 99% of freshwater pearls originate) had perfected a means of creating bigger, rounder, and whiter freshwater pearls. These superior mussel pearls now sell well at Tiffany's and other prestigious jewelry stores (though at slightly lower prices than saltwater pearls). What is the likely effect of this innovation on the cross-elasticity of demand for saltwater pearls given a change in the price of freshwater pearls?

Problems

15. Calculate the price and cross-price elasticities of demand for coconut oil. The coconut oil demand function (Buschena and Perloff, 1991) is

$$Q = 1{,}200 - 9.5p + 16.2p_p + 0.2Y,$$

where Q is the quantity of coconut oil demanded in thousands of metric tons per year, p is the price of coconut oil in cents per pound, p_p is the price of palm oil in cents per pound, and Y is the income of consumers. Assume that p is initially 45¢ per pound, p_p is 31¢ per pound, and Q is 1,275 thousand metric tons per year.

16. Using the coconut oil demand function from Problem 15, calculate the income elasticity of demand for coconut oil. (If you do not have all the numbers necessary to calculate numerical answers, write your answers in terms of variables.)
17. The supply curve is $Q = g + hp$. Write a formula for the elasticity of supply in terms of p (and not Q). Now give one entirely in terms of Q.
18. Suppose that the demand function for apple cider is estimated to be $Q = 100 - p$, where p is the price paid by consumers in cents per bottle and Q is the quantity demanded in hundreds of thousands of bottles per day. The supply curve for cider is estimated to be $Q = \frac{1}{4}p$. Calculate the equilibrium price for bottles of cider and the equilibrium quantity sold. Illustrate using a diagram. An environmental group suggests that the government impose a specific tax per bottled beverage of 20¢, to be

paid when consumers buy cider and to be used by the government to defray the costs of cleaning up bottle litter. Determine the effects of a 20¢ tax per bottle on the equilibrium price paid by consumers and on the equilibrium quantity sold. What price do the cider-producing firms receive? Discuss how the tax may improve the environment.

19. A constant elasticity supply curve, $Q = Bp^{\eta}$, intersects a constant elasticity demand curve, $Q = Ap^{\varepsilon}$, where A, B, η, and ε are constants. What is the incidence of a \$1 specific tax? Does your answer depend on where the supply curve intersects the demand curve? Interpret your result.

20. A constant elasticity supply curve, $Q = Bp^{\eta}$, intersects a linear demand curve, $Q = a - bp$. What is the incidence of a \$1 specific tax? Does your answer depend on where the supply curve intersects the demand curve? Interpret your result.

21. Use math to show that, as the supply curve at the equilibrium becomes nearly perfectly elastic, the entire incidence of the tax falls on consumers.

22. Use calculus to show that an increase in a specific sales tax τ reduces quantity by less and tax revenue more, the less elastic the demand curve. (*Hint:* The quantity demanded depends on its price, which in turn depends on the specific tax, $Q(p(\tau))$, and tax revenue is $R = pQ(p(\tau))$.)

23. If the inverse demand function is $p = a - bQ$ and the inverse supply function is $p = c + dQ$, show that the incidence of a specific tax of τ per unit falling on consumers is $b/(b + d) = \eta/(\eta - \varepsilon)$.