Individual and Market Demand

4

Chapter 3 laid the foundation for the theory of consumer demand. We discussed the nature of consumer preferences and saw how, given budget constraints, consumers choose market baskets that maximize utility. From here it's a short step to analyzing demand and showing how the demand for a good depends on its price, the prices of other goods, and income.

Our analysis of demand proceeds in six steps:

1. We begin by deriving the demand curve for an individual consumer. Because we know how changes in price and income affect a person's budget line, we can determine how they affect consumption choice. We will use this information to see how the quantity of a good demanded varies in response to price changes as we move along an individual's demand curve. We will also see how this demand curve shifts in response to changes in the individual's income.
2. With this foundation, we will examine the effect of a price change in more detail. When the price of a good goes up, individual demand for it can change in two ways. First, because it has now become more expensive relative to other goods, consumers will buy less of it and more of other goods. Second, the higher price reduces the consumer's purchasing power. This reduction is just like a reduction in income and will lead to a reduction in consumer demand. By analyzing these two distinct effects, we will better understand the characteristics of demand.
3. Next, we will see how individual demand curves can be aggregated to determine the market demand curve. We will also study the characteristics of market demand and see why the demands for some kinds of goods differ considerably from the demands for others.
4. We will go on to show how market demand curves can be used to measure the benefits that people receive when they consume products, above and beyond the expenditures they make. This information will be especially important later, when we study the effects of government intervention in a market.
5. We then describe the effects of *network externalities*—i.e., what happens when a person's demand for a good also depends on the demands of *other* people. These effects play a crucial role in the demands for many high-tech products, such as computer hardware and software, and telecommunications systems.
6. Finally, we will briefly describe some of the methods that economists use to obtain empirical information about demand.

CHAPTER OUTLINE

LIST OF EXAMPLES

4.1 INDIVIDUAL DEMAND

This section shows how the demand curve of an individual consumer follows from the consumption choices that a person makes when faced with a budget constraint. To illustrate these concepts graphically, we will limit the available goods to food and clothing, and we will rely on the utility-maximization approach described in Section 3.3 (page 86).

In §3.3, we explain how a consumer chooses the market basket on the highest indifference curve that touches the consumer's budget line.

Price Changes

We begin by examining ways in which the consumption of food and clothing changes when the price of food changes. Figure 4.1 shows the consumption choices that a person will make when allocating a fixed amount of income between the two goods.

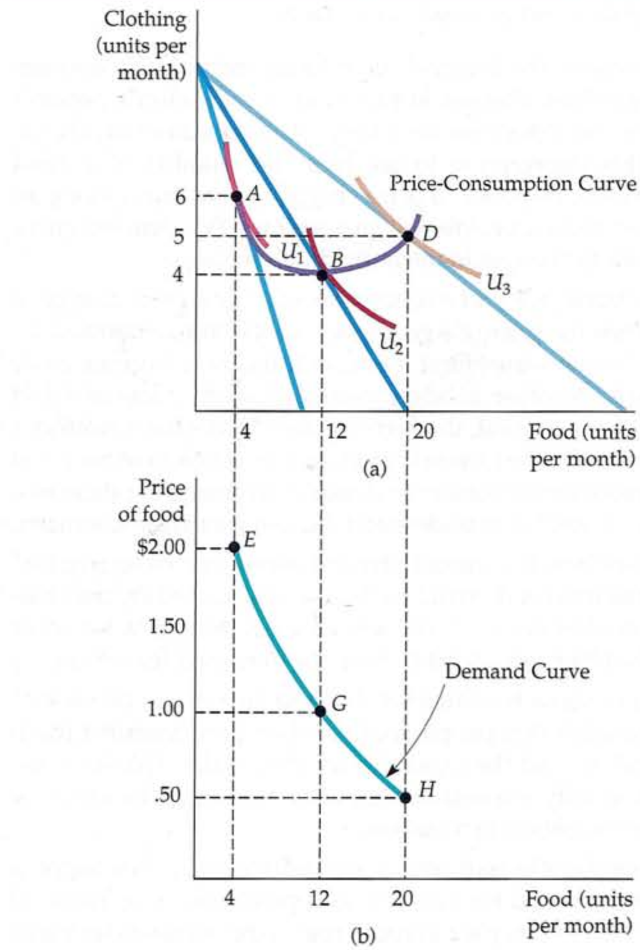

FIGURE 4.1 Effect of Price Changes

A reduction in the price of food, with income and the price of clothing fixed, causes this consumer to choose a different market basket. In **(a)**, the baskets that maximize utility for various prices of food (point *A*, \$2; *B*, \$1; *D*, \$0.50) trace out the price-consumption curve. Part **(b)** gives the demand curve, which relates the price of food to the quantity demanded. (Points *E*, *G*, and *H* correspond to points *A*, *B*, and *D*, respectively).

Initially, the price of food is \$1, the price of clothing \$2, and the consumer's income \$20. The utility-maximizing consumption choice is at point B in Figure 4.1(a). Here, the consumer buys 12 units of food and 4 units of clothing, thus achieving the level of utility associated with indifference curve U_2.

Now look at Figure 4.1(b), which shows the relationship between the price of food and the quantity demanded. The horizontal axis measures the quantity of food consumed, as in Figure 4.1(a), but the vertical axis now measures the price of food. Point G in Figure 4.1(b) corresponds to point B in Figure 4.1(a). At G, the price of food is \$1, and the consumer purchases 12 units of food.

Suppose the price of food increases to \$2. As we saw in Chapter 3, the budget line in Figure 4.1(a) rotates inward about the vertical intercept, becoming twice as steep as before. The higher relative price of food has increased the magnitude of the slope of the budget line. The consumer now achieves maximum utility at A, which is found on a lower indifference curve, U_1. (Because the price of food has risen, the consumer's purchasing power—and thus attainable utility—has fallen.) At A, the consumer chooses 4 units of food and 6 units of clothing. In Figure 4.1(b), this modified consumption choice is at E, which shows that at a price of \$2, 4 units of food are demanded.

In §3.2, we explain how the budget line shifts in response to a price change.

Finally, what will happen if the price of food *decreases* to 50 cents? Because the budget line now rotates outward, the consumer can achieve the higher level of utility associated with indifference curve U_3 in Figure 4.1(a) by selecting D, with 20 units of food and 5 units of clothing. Point H in Figure 4.1(b) shows the price of 50 cents and the quantity demanded of 20 units of food.

The Individual Demand Curve

We can go on to include all possible changes in the price of food. In Figure 4.1(a), the **price-consumption curve** traces the utility-maximizing combinations of food and clothing associated with every possible price of food. Note that as the price of food falls, attainable utility increases and the consumer buys more food. This pattern of increasing consumption of a good in response to a decrease in price almost always holds. But what happens to the consumption of clothing as the price of food falls? As Figure 4.1(a) shows, the consumption of clothing may either increase or decrease. The consumption of both food *and* clothing can increase because the decrease in the price of food has increased the consumer's ability to purchase both goods.

• **price-consumption curve** Curve tracing the utility-maximizing combinations of two goods as the price of one changes.

An **individual demand curve** relates the quantity of a good that a single consumer will buy to the price of that good. In Figure 4.1(b), the individual demand curve relates the quantity of food that the consumer will buy to the price of food. This demand curve has two important properties:

• **individual demand curve** Curve relating the quantity of a good that a single consumer will buy to its price.

1. ***The level of utility that can be attained changes as we move along the curve.*** The lower the price of the product, the higher the level of utility. Note from Figure 4.1(a) that a higher indifference curve is reached as the price falls. Again, this result simply reflects the fact that as the price of a product falls, the consumer's purchasing power increases.
2. ***At every point on the demand curve, the consumer is maximizing utility by satisfying the condition that the marginal rate of substitution (MRS) of food for clothing equals the ratio of the prices of food and clothing.*** As the price of food falls, the price ratio and the MRS also fall. In Figure 4.1(b), the price ratio falls from 1 (\$2/\$2) at E (because the curve U_1 is tangent to a budget line with a slope of −1 at A) to 1/2 (\$1/\$2) at G, to 1/4 (\$0.50/\$2)

In §3.1, we introduce the marginal rate of substitution (MRS) as a measure of the maximum amount of one good that the consumer is willing to give up in order to obtain one unit of another good.

at H. Because the consumer is maximizing utility, the MRS of food for clothing decreases as we move down the demand curve. This phenomenon makes intuitive sense because it tells us that the relative value of food falls as the consumer buys more of it.

The fact that the MRS varies along the individual's demand curve tells us something about how consumers value the consumption of a good or service. Suppose we were to ask a consumer how much she would be willing to pay for an additional unit of food when she is currently consuming 4 units. Point E on the demand curve in Figure 4.1(b) provides the answer: \$2. Why? As we pointed out above, because the MRS of food for clothing is 1 at E, one additional unit of food is worth one additional unit of clothing. But a unit of clothing costs \$2, which is, therefore, the value (or marginal benefit) obtained by consuming an additional unit of food. Thus, as we move down the demand curve in Figure 4.1(b), the MRS falls. Likewise, the value that the consumer places on an additional unit of food falls from \$2 to \$1 to \$0.50.

Income Changes

We have seen what happens to the consumption of food and clothing when the price of food changes. Now let's see what happens when income changes.

The effects of a change in income can be analyzed in much the same way as a price change. Figure 4.2(a) shows the consumption choices that a consumer will make when allocating a fixed income to food and clothing when the price of food is \$1 and the price of clothing \$2. As in Figure 4.1(a), the quantity of clothing is measured on the vertical axis and the quantity of food on the horizontal axis. Income changes appear as changes in the budget line in Figure 4.2(a). Initially, the consumer's income is \$10. The utility-maximizing consumption choice is then at A, at which point she buys 4 units of food and 3 units of clothing.

This choice of 4 units of food is also shown in Figure 4.2(b) as E on demand curve D_1. Demand curve D_1 is the curve that would be traced out if we held income fixed at \$10 *but varied the price of food*. Because we are holding the price of food constant, we will observe only a single point E on this demand curve.

What happens if the consumer's income is increased to \$20? Her budget line then shifts outward parallel to the original budget line, allowing her to attain the utility level associated with indifference curve U_2. Her optimal consumption choice is now at B, where she buys 10 units of food and 5 units of clothing. In Figure 4.2(b) her consumption of food is shown as G on demand curve D_2. D_2 is the demand curve that would be traced out if we held income fixed at \$20 but varied the price of food. Finally, note that if her income increases to \$30, she chooses D, with a market basket containing 16 units of food (and 7 units of clothing), represented by H in Figure 4.2(b).

• income-consumption curve Curve tracing the utility-maximizing combinations of two goods as a consumer's income changes.

We could go on to include all possible changes in income. In Figure 4.2(a), the **income-consumption curve** traces out the utility-maximizing combinations of food and clothing associated with every income level. The income-consumption curve in Figure 4.2 slopes upward because the consumption of both food and clothing increases as income increases. Previously, we saw that a change in the price of a good corresponds to *a movement along a demand curve*. Here, the situation is different. Because each demand curve is measured for a particular level of income, any change in income must lead to *a shift in the demand curve itself*. Thus A on the income-consumption curve in Figure 4.2(a) corresponds to E on demand curve D_1 in Figure 4.2(b); B corresponds to G on a different demand curve D_2. The upward-sloping income-consumption curve implies that an

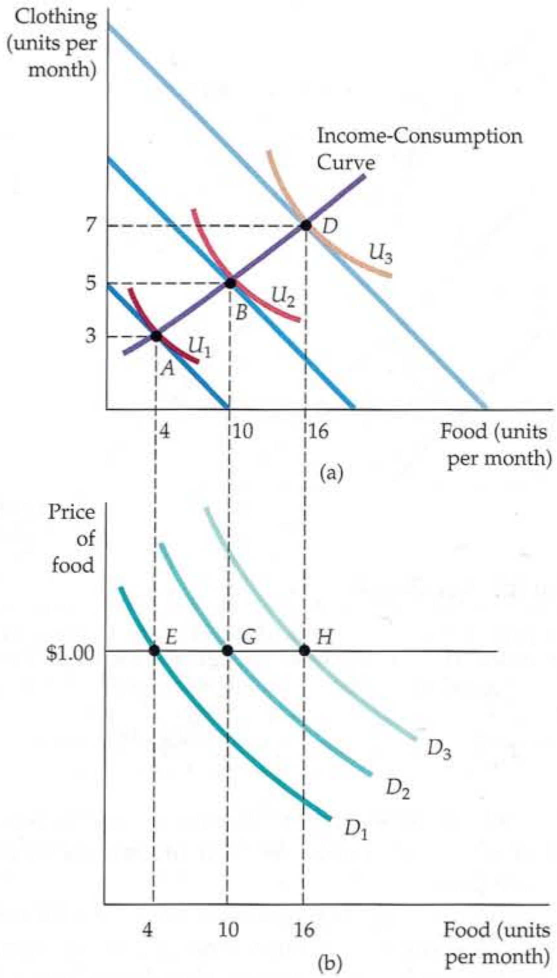

FIGURE 4.2 Effect of Income Changes

An increase in income, with the prices of all goods fixed, causes consumers to alter their choice of market baskets. In part **(a)**, the baskets that maximize consumer satisfaction for various incomes (point *A*, \$10; *B*, \$20; *D*, \$30) trace out the income-consumption curve. The shift to the right of the demand curve in response to the increases in income is shown in part **(b)**. (Points *E*, *G*, and *H* correspond to points *A*, *B*, and *D*, respectively.)

increase in income causes a shift to the right in the demand curve—in this case from D_1 to D_2 to D_3.

Normal versus Inferior Goods

When the income-consumption curve has a positive slope, the quantity demanded increases with income. As a result, the income elasticity of demand is positive. The greater the shifts to the right of the demand curve, the larger the income elasticity. In this case, the goods are described as *normal*: Consumers want to buy more of them as their incomes increase.

In §2.4, we explain that the income elasticity of demand is the percentage change in the quantity demanded resulting from a 1-percent increase in income.

In some cases, the quantity demanded *falls* as income increases; the income elasticity of demand is negative. We then describe the good as *inferior*. The term

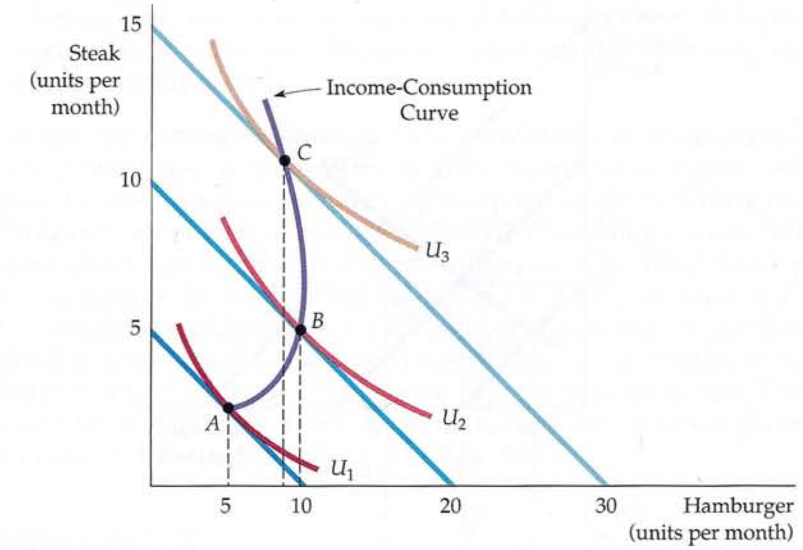

FIGURE 4.3 An Inferior Good

An increase in a person's income can lead to less consumption of one of the two goods being purchased. Here, hamburger, though a normal good between *A* and *B*, becomes an inferior good when the income-consumption curve bends backward between *B* and *C*.

inferior simply means that consumption falls when income rises. Hamburger, for example, is inferior for some people: As their income increases, they buy less hamburger and more steak.

Figure 4.3 shows the income-consumption curve for an inferior good. For relatively low levels of income, both hamburger and steak are normal goods. As income rises, however, the income-consumption curve bends backward (from point *B* to *C*). This shift occurs because hamburger has become an inferior good—its consumption has fallen as income has increased.

Engel Curves

• **Engel curve** Curve relating the quantity of a good consumed to income.

Income-consumption curves can be used to construct **Engel curves**, which relate the quantity of a good consumed to an individual's income. Figure 4.4 shows how such curves are constructed for two different goods. Figure 4.4(a), which shows an upward-sloping Engel curve, is derived directly from Figure 4.2(a). In both figures, as the individual's income increases from \$10 to \$20 to \$30, her consumption of food increases from 4 to 10 to 16 units. Recall that in Figure 4.2(a) the vertical axis measured units of clothing consumed per month and the horizontal axis units of food per month; changes in income were reflected as shifts in the budget line. In Figures 4.4(a) and (b), we have replotted the data to put income on the vertical axis, while keeping food and hamburger on the horizontal.

The upward-sloping Engel curve in Figure 4.4(a)—like the upward-sloping income-consumption curve in Figure 4.2(a)—applies to all normal goods. Note that an Engel curve for clothing would have a similar shape (clothing consumption increases from 3 to 5 to 7 units as income increases).

Figure 4.4(b), derived from Figure 4.3, shows the Engel curve for hamburger. We see that hamburger consumption increases from 5 to 10 units as income

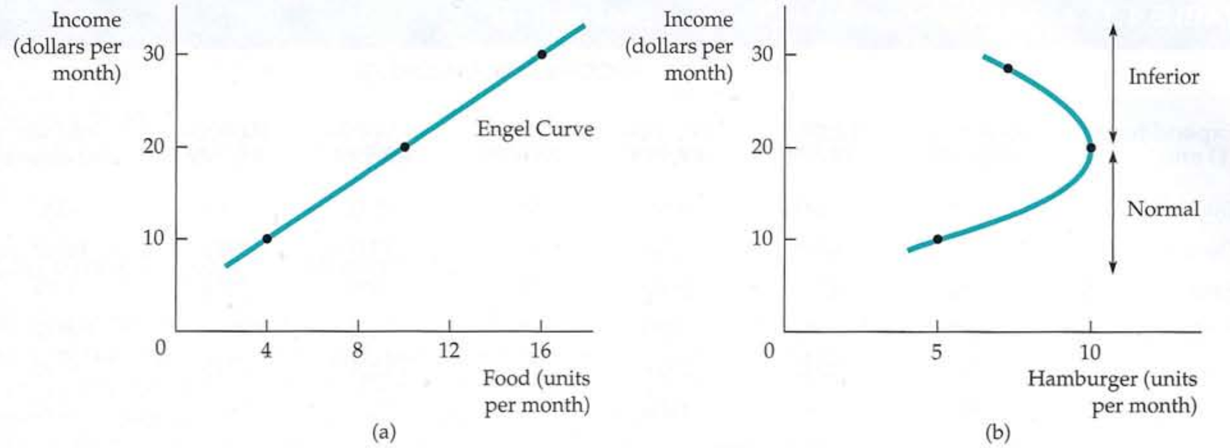

FIGURE 4.4 Engel Curves

Engel curves relate the quantity of a good consumed to income. In **(a)**, food is a normal good and the Engel curve is upward sloping. In **(b)**, however, hamburger is a normal good for income less than \$20 per month and an inferior good for income greater than \$20 per month.

increases from \$10 to \$20. As income increases further, from \$20 to \$30, consumption falls to 8 units. The portion of the Engel curve that slopes downward is the income range within which hamburger is an inferior good.

EXAMPLE 4.1 Consumer Expenditures in the United States

The Engel curves we just examined apply to individual consumers. However, we can also derive Engel curves for groups of consumers. This information is particularly useful if we want to see how consumer spending varies among different income groups. Table 4.1 illustrates spending patterns for several items taken from a survey by the U.S. Bureau of Labor Statistics. Although the data are averaged over many households, they can be interpreted as describing the expenditures of a typical family.

Note that the data relate *expenditures* on a particular item rather than the *quantity* of the item to income. The first two items, entertainment and owned dwellings, are consumption goods for which the income elasticity of demand is high. Average family expenditures on entertainment increase more than fivefold when we move from the lowest to highest income group. The same pattern applies to the purchase of homes: There is a more than a threefold increase in expenditures from the lowest to the highest category.

In contrast, expenditures on *rental* housing actually *fall* as income rises. This pattern reflects the fact that most higher-income individuals own rather than rent homes. Thus rental housing is an inferior good, at least for incomes above

TABLE 4.1 Annual U.S. Household Consumer Expenditures

	INCOME GROUP (2005$)						
Expenditures ($) on:	**Less than $10,000**	**10,000–19,999**	**20,000–29,999**	**30,000–39,999**	**40,000–49,999**	**50,000–69,999**	**70,000 and above**
Entertainment	844	947	1191	1677	1933	2402	4542
Owned Dwelling	4272	4716	5701	6776	7771	8972	14763
Rented Dwelling	2672	2779	2980	2977	2818	2255	1379
Health Care	1108	1874	2241	2361	2778	2746	3812
Food	2901	3242	3942	4552	5234	6570	9247
Clothing	861	884	1106	1472	1450	1961	3245

Source: U.S. Department of Labor, Bureau of Labor Statistics, "Consumer Expenditure Survey, Annual Report 2005."

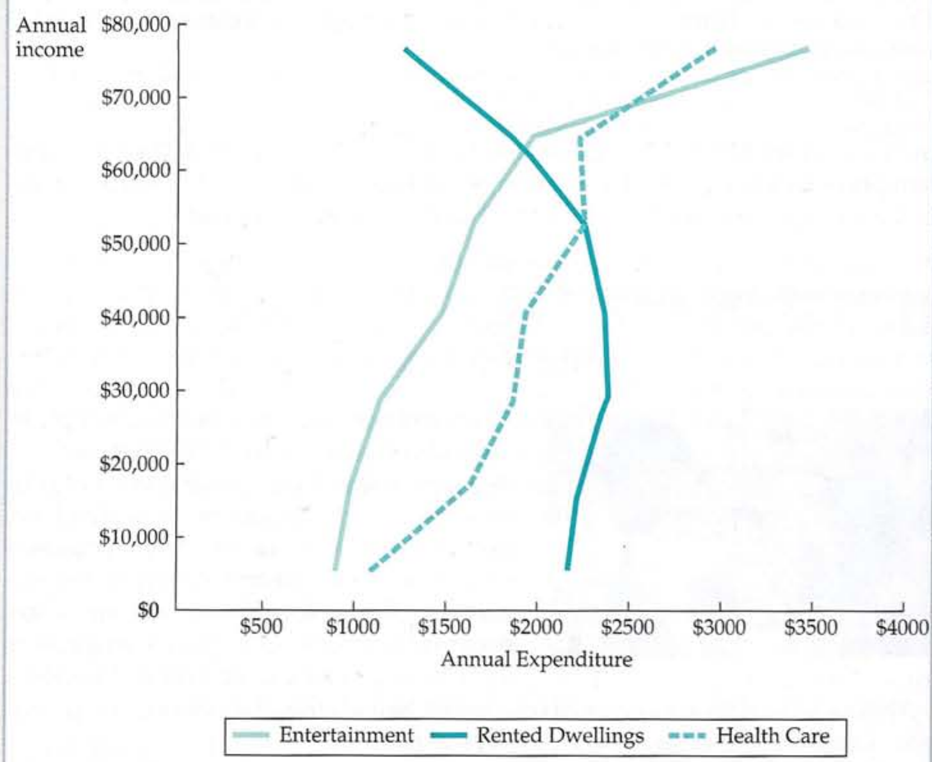

FIGURE 4.5 Engel Curves for U.S. Consumers

Average per-household expenditures on rented dwellings, health care, and entertainment are plotted as functions of annual income. Health care and entertainment are normal goods, as expenditures increase with income. Rental housing, however, is an inferior good for incomes above $35,000.

$35,000 per year. Finally, note that health care, food, and clothing are consumption items for which the income elasticities are positive, but not as high as for entertainment or owner-occupied housing.

The data in Table 4.1 for rented dwellings, health care, and entertainment have been plotted in Figure 4.5. Observe in the three Engel curves that as income rises, expenditures on entertainment increase rapidly, while expenditures on rental housing increase when income is low, but decrease once income exceeds $35,000.

Substitutes and Complements

The demand curves that we graphed in Chapter 2 showed the relationship between the price of a good and the quantity demanded, with preferences, income, and the prices of all other goods held constant. For many goods, demand is related to the consumption and prices of other goods. Baseball bats and baseballs, hot dogs and mustard, and computer hardware and software are all examples of goods that tend to be used together. Other goods, such as cola and diet cola, owner-occupied houses and rental apartments, movie tickets and videocassette rentals, tend to substitute for one another.

Recall from Section 2.1 (page 22) that two goods are *substitutes* if an increase in the price of one leads to an increase in the quantity demanded of the other. If the price of a movie ticket rises, we would expect individuals to rent more videos, because movie tickets and videos are substitutes. Similarly, two goods are *complements* if an increase in the price of one good leads to a decrease in the quantity demanded of the other. If the price of gasoline goes up, causing gasoline consumption to fall, we would expect the consumption of motor oil to fall as well, because gasoline and motor oil are used together. Two goods are *independent* if a change in the price of one good has no effect on the quantity demanded of the other.

One way to see whether two goods are complements or substitutes is to examine the price-consumption curve. Look again at Figure 4.1 (page 112). Note that in the downward-sloping portion of the price-consumption curve, food and clothing are substitutes: The lower price of food leads to a lower consumption of clothing (perhaps because as food expenditures increase, less income is available to spend on clothing). Similarly, food and clothing are complements in the upward-sloping portion of the curve: The lower price of food leads to higher clothing consumption (perhaps because the consumer eats more meals at restaurants and must be suitably dressed).

The fact that goods can be complements or substitutes suggests that when studying the effects of price changes in one market, it may be important to look at the consequences in related markets. (Interrelationships among markets are discussed in more detail in Chapter 16.) Determining whether two goods are complements, substitutes, or independent goods is ultimately an empirical question. To answer the question, we need to look at the ways in which the demand for the first good shifts (if at all) in response to a change in the price of the second. This question is more difficult than it sounds because lots of things are likely to be changing at the same time that the price of the first good changes. In fact, Section 4.6 of this chapter is devoted to examining ways to distinguish empirically among the many possible explanations for a change in the demand for the second good. First, however, it will be useful to undertake a basic theoretical exercise. In the next section, we delve into the ways in which a change in the price of a good can affect consumer demand.

4.2 INCOME AND SUBSTITUTION EFFECTS

A fall in the price of a good has two effects:

1. ***Consumers will tend to buy more of the good that has become cheaper and less of those goods that are now relatively more expensive.*** This response to a change in the relative prices of goods is called the *substitution effect*.
2. ***Because one of the goods is now cheaper, consumers enjoy an increase in real purchasing power.*** They are better off because they can buy the same amount of the good for less money, and thus have money left over for additional purchases. The change in demand resulting from this change in real purchasing power is called the *income effect*.

Normally, these two effects occur simultaneously, but it will be useful to distinguish between them for purposes of analysis. The specifics are illustrated in Figure 4.6, where the initial budget line is *RS* and there are two goods, food and clothing. Here, the consumer maximizes utility by choosing the market basket at *A*, thereby obtaining the level of utility associated with the indifference curve U_1.

Now let's see what happens if the price of food falls, causing the budget line to rotate outward to line *RT*. The consumer now chooses the market basket at *B*

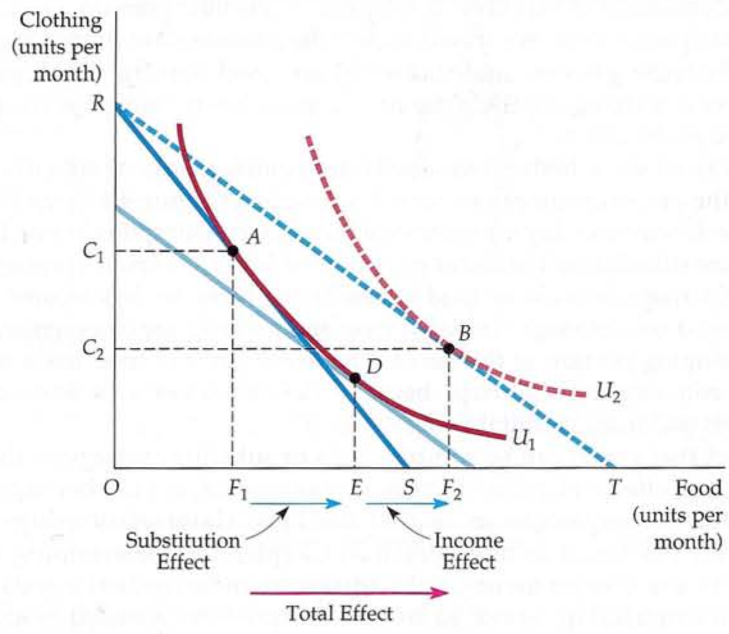

FIGURE 4.6 Income and Substitution Effects: Normal Good

A decrease in the price of food has both an income effect and a substitution effect. The consumer is initially at *A*, on budget line *RS*. When the price of food falls, consumption increases by F_1F_2 as the consumer moves to *B*. The substitution effect F_1E (associated with a move from *A* to *D*) changes the relative prices of food and clothing but keeps real income (satisfaction) constant. The income effect EF_2 (associated with a move from *D* to *B*) keeps relative prices constant but increases purchasing power. Food is a normal good because the income effect EF_2 is positive.

on indifference curve U_2. Because market basket B was chosen even though market basket A was feasible, we know (from our discussion of revealed preference in Section 3.4) that B is preferred to A. Thus, the reduction in the price of food allows the consumer to increase her level of satisfaction—her purchasing power has increased. The total change in the consumption of food caused by the lower price is given by F_1F_2. Initially, the consumer purchased OF_1 units of food, but after the price change, food consumption has increased to OF_2. Line segment F_1F_2, therefore, represents the increase in desired food purchases.

In §3.4, we show how information about consumer preferences is revealed by consumption choices made.

Substitution Effect

The drop in price has both a substitution effect and an income effect. The **substitution effect** is *the change in food consumption associated with a change in the price of food, with the level of utility held constant*. The substitution effect captures the change in food consumption that occurs as a result of the price change that makes food relatively cheaper than clothing. This substitution is marked by a movement along an indifference curve. In Figure 4.6, the substitution effect can be obtained by drawing a budget line which is parallel to the new budget line RT (reflecting the lower relative price of food), but which is just tangent to the original indifference curve U_1 (holding the level of satisfaction constant). The new, lower imaginary budget line reflects the fact that nominal income was reduced in order to accomplish our conceptual goal of isolating the substitution effect. Given that budget line, the consumer chooses market basket D and consumes OE units of food. The line segment F_1E thus represents the substitution effect.

• **substitution effect** Change in consumption of a good associated with a change in its price, with the level of utility held constant.

Figure 4.6 makes it clear that when the price of food declines, the substitution effect always leads to an increase in the quantity of food demanded. The explanation lies in the fourth assumption about consumer preferences discussed in Section 3.1—namely, that indifference curves are convex. Thus, with the convex indifference curves shown in the figure, the point that maximizes satisfaction on the new imaginary budget line parallel to RT must lie below and to the right of the original point of tangency.

Income Effect

Now let's consider the **income effect**: *the change in food consumption brought about by the increase in purchasing power, with relative prices held constant*. In Figure 4.6, we can see the income effect by moving from the imaginary budget line that passes through point D to the parallel budget line, RT, which passes through B. The consumer chooses market basket B on indifference curve U_2 (because the lower price of food has increased her level of utility). The increase in food consumption from OE to OF_2 is the measure of the income effect, which is positive, because food is a *normal good* (consumers will buy more of it as their incomes increase). Because it reflects a movement from one indifference curve to another, the income effect measures the change in the consumer's purchasing power.

• **income effect** Change in consumption of a good resulting from an increase in purchasing power, with relative prices held constant.

We have seen in Figure 4.6 that the total effect of a change in price is given theoretically by the sum of the substitution effect and the income effect:

$$\text{Total Effect } (F_1F_2) = \text{Substitution Effect } (F_1E) + \text{Income Effect } (EF_2)$$

Recall that the direction of the substitution effect is always the same: A decline in price leads to an increase in consumption of the good. However, the income effect can move demand in either direction, depending on whether the good is normal or inferior.

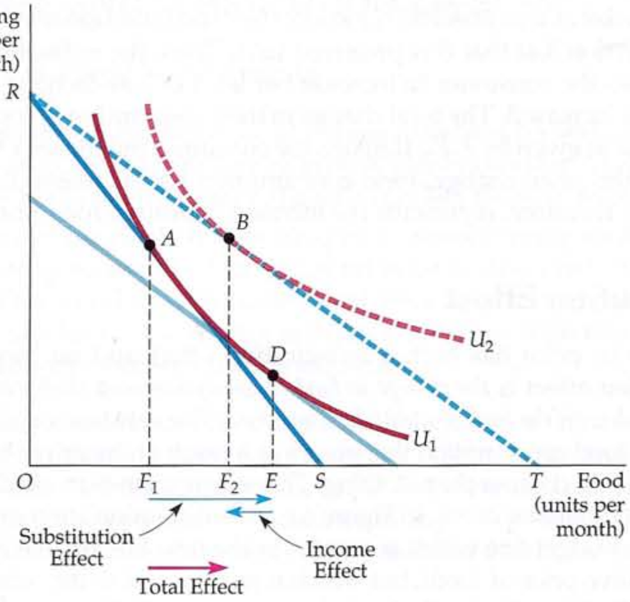

FIGURE 4.7 Income and Substitution Effects: Inferior Good

The consumer is initially at A on budget line RS. With a decrease in the price of food, the consumer moves to B. The resulting change in food purchased can be broken down into a substitution effect, F_1E (associated with a move from A to D), and an income effect, EF_2 (associated with a move from D to B). In this case, food is an inferior good because the income effect is negative. However, because the substitution effect exceeds the income effect, the decrease in the price of food leads to an increase in the quantity of food demanded.

A good is *inferior* when the income effect is negative: As income rises, consumption falls. Figure 4.7 shows income and substitution effects for an inferior good. The negative income effect is measured by line segment EF_2. Even with inferior goods, the income effect is rarely large enough to outweigh the substitution effect. As a result, when the price of an inferior good falls, its consumption almost always increases.

A Special Case: The Giffen Good

• **Giffen good** Good whose demand curve slopes upward because the (negative) income effect is larger than the substitution effect.

Theoretically, the income effect may be large enough to cause the demand curve for a good to slope upward. We call such a good a **Giffen good**, and Figure 4.8 shows its income and substitution effects. Initially, the consumer is at A, consuming relatively little clothing and much food. Now the price of food declines. The decline in the price of food frees enough income so that the consumer desires to buy more clothing and fewer units of food, as illustrated by B. Revealed preference tells us that the consumer is better off at B rather than A even though less food is consumed.

Though intriguing, the Giffen good is rarely of practical interest because it requires a large negative income effect. But the income effect is usually small: Individually, most goods account for only a small part of a consumer's budget. Large income effects are often associated with normal rather than inferior goods (e.g., total spending on food or housing).

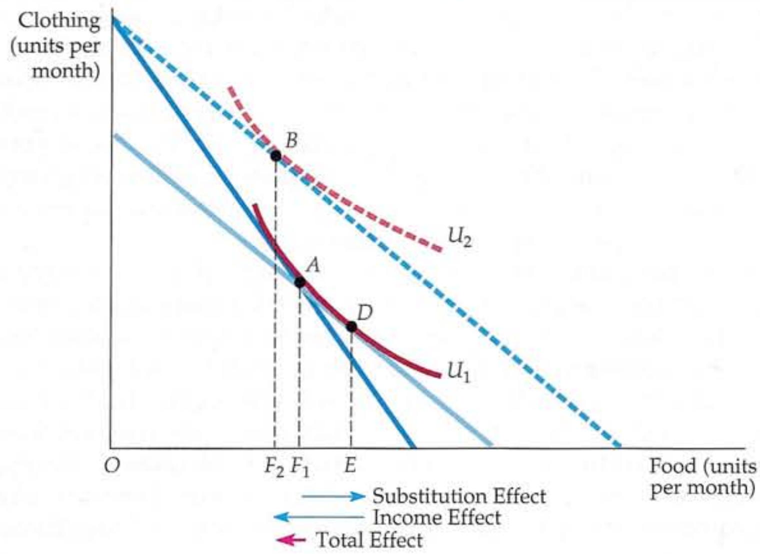

FIGURE 4.8 Upward-Sloping Demand Curve: The Giffen Good

When food is an inferior good, and when the income effect is large enough to dominate the substitution effect, the demand curve will be upward-sloping. The consumer is initially at point A, but, after the price of food falls, moves to B and consumes less food. Because the income effect EF_2 is larger than the substitution effect F_1E, the decrease in the price of food leads to a lower quantity of food demanded.

EXAMPLE 4.2 The Effects of a Gasoline Tax

In part to conserve energy and in part to raise revenues, the U.S. government has often considered increasing the federal gasoline tax. In 1993, for example, a modest 7.5 cent increase was enacted as part of a larger budget-reform package. This increase was much less than the increase that would have been necessary to put U.S. gasoline prices on a par with those in Europe. Because an important goal of higher gasoline taxes is to discourage gasoline consumption, the government has also considered ways of passing the resulting income back to consumers. One popular suggestion is a rebate program in which tax revenues would be returned to households on an equal per-capita basis. What would be the effect of such a program?

Let's begin by focusing on the effect of the program over a period of five years. The relevant price elasticity of demand is about –0.5.[1] Suppose that a low-income consumer uses about 1200 gallons of gasoline per year, that gasoline costs $1 per gallon, and that our consumer's annual income is $9000.

Figure 4.9 shows the effect of the gasoline tax. (The graph has intentionally been drawn not to scale so that the effects we are discussing can be seen more clearly.) The original budget line is AB, and the consumer maximizes utility (on

[1]We saw in Chapter 2 that the price elasticity of demand for gasoline varied substantially from the short run to the long run, ranging from –0.11 in the short run to –1.17 in the long run.

indifference curve U_2) by consuming the market basket at C, buying 1200 gallons of gasoline and spending \$7800 on other goods. If the tax is 50 cents per gallon, price will increase by 50 percent, shifting the new budget line to AD.[2] (Recall that when price changes and income stays fixed, the budget line rotates around a pivot point on the unchanged axis.) With a price elasticity of –0.5, consumption will decline 25 percent, from 1200 to 900 gallons, as shown by the utility-maximizing point E on indifference curve U_1 (for every 1-percent increase in the price of gasoline, quantity demanded drops by 1/2 percent).

The rebate program, however, partially counters this effect. Suppose that because the tax revenue per person is about \$450 (900 gallons times 50 cents per gallon), each consumer receives a \$450 rebate. How does this increased income affect gasoline consumption? The effect can be shown graphically by shifting the budget line upward by \$450, to line FJ, which is parallel to AD. How much gasoline does our consumer buy now? In Chapter 2, we saw that the income elasticity of demand for gasoline is approximately 0.3. Because \$450 represents a 5-percent increase in income (\$450/\$9000 = 0.05), we would expect the rebate to increase consumption by 1.5 percent (0.3 times 5 percent) of 900 gallons, or 13.5

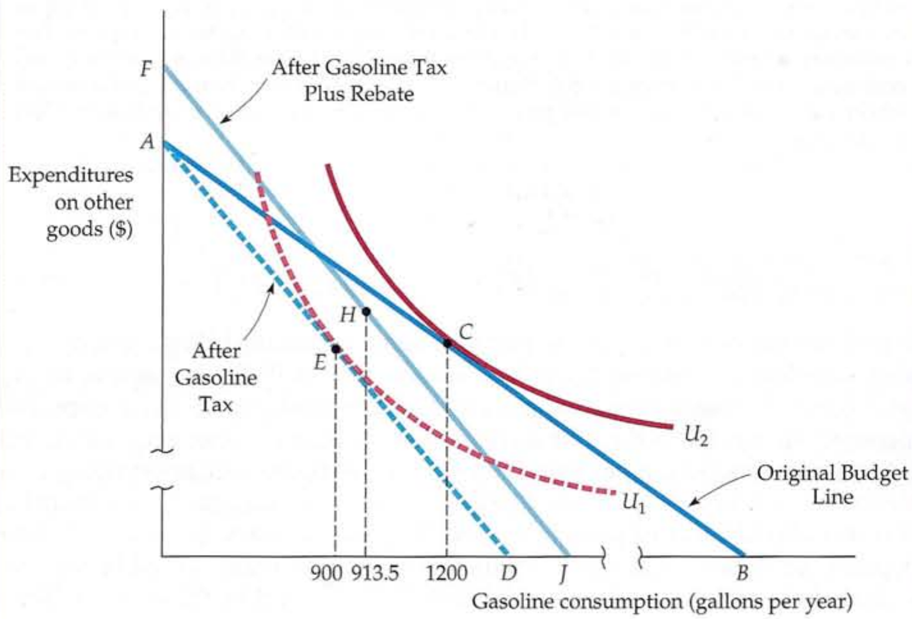

FIGURE 4.9 Effect of a Gasoline Tax with a Rebate

A gasoline tax is imposed when the consumer is initially buying 1200 gallons of gasoline at point C. After the tax takes effect, the budget line shifts from AB to AD and the consumer maximizes his preferences by choosing E, with a gasoline consumption of 900 gallons. However, when the proceeds of the tax are rebated to the consumer, his consumption increases somewhat, to 913.5 gallons at H. Despite the rebate program, the consumer's gasoline consumption has fallen, as has his level of satisfaction.

[2]To simplify the example, we have assumed that the entire tax is paid by consumers in the form of a higher price. A broader analysis of tax shifting is presented in Chapter 9.

gallons. The new utility-maximizing consumption choice at H reflects this expectation. (We omitted the indifference curve that is tangent at H to simplify the diagram.) With the rebate program, the tax would reduce gasoline consumption by 286.5 gallons, from 1200 to 913.5. Because the income elasticity of demand for gasoline is relatively low, the income effect of the rebate program is dominated by the substitution effect, and the program with a rebate does indeed reduce consumption.

In order to put a real tax-rebate program into effect, Congress would have to solve a variety of practical problems. First, incoming tax receipts and rebate expenditures would vary from year to year, making it difficult to plan the budgeting process. For example, the tax rebate of $450 in the first year of the program is an increase in income. During the second year, it would lead to some increase in gasoline consumption among the low-income consumers that we are studying. With increased consumption, however, the tax paid and the rebate received by an individual will increase in the second year. As a result, it may be difficult to predict the size of the program budget.

Figure 4.9 reveals that the gasoline tax program makes this particular low-income consumer slightly worse off because H lies just below indifference curve U_2. Of course, some low-income consumers might actually benefit from the program (if, for example, they consume less gasoline on average than the group of consumers whose consumption determines the selected rebate). Nevertheless, the substitution effect caused by the tax will make consumers, on average, worse off.

Why, then, introduce such a program? Those who support gasoline taxes argue that they promote national security (by reducing dependence on foreign oil) and encourage conservation, thus helping to slow global warming by reducing the buildup of carbon dioxide in the atmosphere. We will further examine the impact of a gasoline tax in Chapter 9.

4.3 MARKET DEMAND

So far, we have discussed the demand curve for an individual consumer. Now we turn to the market demand curve. Recall from Chapter 2 that a market demand curve shows how much of a good consumers overall are willing to buy as its price changes. In this section, we show how **market demand curves** can be derived as the sum of the individual demand curves of all consumers in a particular market.

• **market demand curve** Curve relating the quantity of a good that all consumers in a market will buy to its price.

From Individual to Market Demand

To keep things simple, let's assume that only three consumers (A, B, and C) are in the market for coffee. Table 4.2 tabulates several points on each consumer's demand curve. The market demand, column (5), is found by adding columns (2), (3), and (4), representing our three consumers, to determine the total quantity demanded at every price. When the price is $3, for example, the total quantity demanded is 2 + 6 + 10, or 18.

Figure 4.10 shows these same three consumers' demand curves for coffee (labeled D_A, D_B, and D_C). In the graph, the market demand curve is the

TABLE 4.2 Determining the Market Demand Curve

(1) Price ($)	(2) Individual A (Units)	(3) Individual B (Units)	(4) Individual C (Units)	(5) Market (Units)
1	6	10	16	32
2	4	8	13	25
3	2	6	10	18
4	0	4	7	11
5	0	2	4	6

horizontal summation of the demands of each consumer. We sum horizontally to find the total amount that the three consumers will demand at any given price. For example, when the price is $4, the quantity demanded by the market (11 units) is the sum of the quantity demanded by *A* (no units), by *B* (4 units), and by *C* (7 units). Because all of the individual demand curves slope downward, the market demand curve will also slope downward. However, even though each of the individual demand curves is a straight line, the market demand curve need not be. In Figure 4.10, for example, the market demand curve is *kinked* because one consumer makes no purchases at prices that the other consumers find acceptable (those above $4).

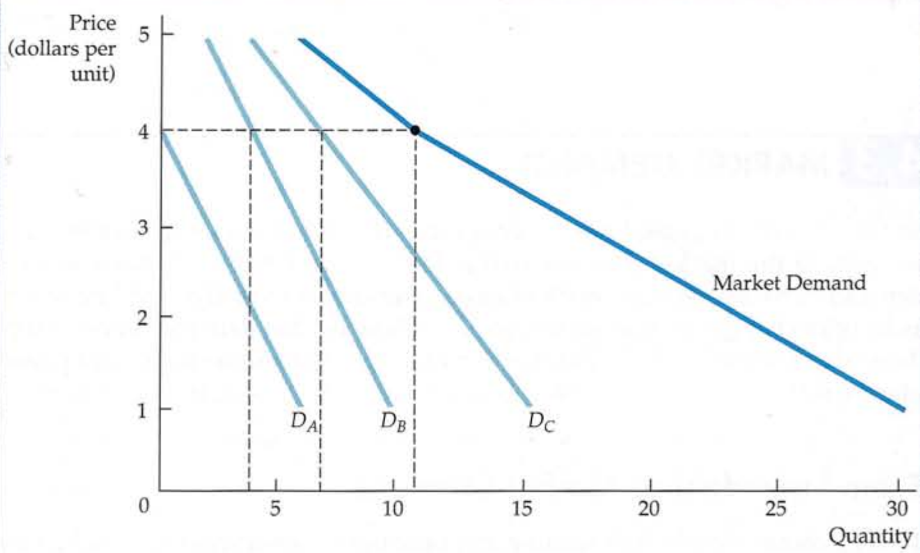

FIGURE 4.10 Summing to Obtain a Market Demand Curve

The market demand curve is obtained by summing our three consumers' demand curves D_A, D_B, and D_C. At each price, the quantity of coffee demanded by the market is the sum of the quantities demanded by each consumer. At a price of $4, for example, the quantity demanded by the market (11 units) is the sum of the quantity demanded by *A* (no units), *B* (4 units), and *C* (7 units).

Two points should be noted as a result of this analysis:

1. ***The market demand curve will shift to the right as more consumers enter the market.***
2. ***Factors that influence the demands of many consumers will also affect market demand.*** Suppose, for example, that most consumers in a particular market earn more income and, as a result, increase their demands for coffee. Because each consumer's demand curve shifts to the right, so will the market demand curve.

The aggregation of individual demands into market demands is not just a theoretical exercise. It becomes important in practice when market demands are built up from the demands of different demographic groups or from consumers located in different areas. For example, we might obtain information about the demand for home computers by adding independently obtained information about the demands of the following groups:

- Households with children
- Households without children
- Single individuals

Or, we might determine U.S. wheat demand by aggregating domestic demand (i.e., by U.S. consumers) and export demand (i.e., by foreign consumers), as we will see in Example 4.3.

Elasticity of Demand

Recall from Section 2.4 (page 34) that the price elasticity of demand measures the percentage change in the quantity demanded resulting from a 1-percent increase in price. Denoting the quantity of a good by Q and its price by P, the *price elasticity of demand* is

In §2.4, we show how the price elasticity of demand describes the responsiveness of consumer demands to changes in price.

$$E_P = \frac{\Delta Q/Q}{\Delta P/P} = \left(\frac{P}{Q}\right)\left(\frac{\Delta Q}{\Delta P}\right) \tag{4.1}$$

(Here, because Δ means "a change in," $\Delta Q/Q$ is the percentage change in Q.)

Inelastic Demand When demand is inelastic (i.e., E_P is less than 1 in absolute value), the quantity demanded is relatively unresponsive to changes in price. As a result, total expenditure on the product increases when the price increases. Suppose, for example, that a family currently uses 1000 gallons of gasoline a year when the price is \$1 per gallon; suppose also that our family's price elasticity of demand for gasoline is –0.5. If the price of gasoline increases to \$1.10 (a 10-percent increase), the consumption of gasoline falls to 950 gallons (a 5-percent decrease). Total expenditure on gasoline, however, will increase from \$1000 (1000 gallons × \$1 per gallon) to \$1045 (950 gallons × \$1.10 per gallon).

Recall from §2.4 that because the magnitude of an elasticity refers to its absolute value, an elasticity of –0.5 is less in magnitude than a –1.0 elasticity.

Elastic Demand In contrast, when demand is elastic (E_P is greater than 1 in absolute value), total expenditure on the product decreases as the price goes up.

Suppose that a family buys 100 pounds of chicken per year at a price of $2 per pound; the price elasticity of demand for chicken is –1.5. If the price of chicken increases to $2.20 (a 10-percent increase), our family's consumption of chicken falls to 85 pounds a year (a 15-percent decrease). Total expenditure on chicken will also fall, from $200 (100 pounds × $2 per pound) to $187 (85 pounds × $2.20 per pound).

isoelastic demand curve Demand curve with a constant price elasticity.

In §2.4, we show that when the demand curve is linear, demand becomes more elastic as the price of the product increases.

Isoelastic Demand When the price elasticity of demand is constant all along the demand curve, we say that the curve is **isoelastic**. Figure 4.11 shows an isoelastic demand curve. Note how this demand curve is bowed inward. In contrast, recall from Section 2.4 what happens to the price elasticity of demand as we move along a *linear demand curve*. Although the slope of the linear curve is constant, the price elasticity of demand is not. It is zero when the price is zero, and it increases in magnitude until it becomes infinite when the price is sufficiently high for the quantity demanded to become zero.

A special case of the isoelastic curve is the *unit-elastic demand curve*: a demand curve with price elasticity always equal to –1, as is the case for the curve in Figure 4.11. In this case, total expenditure remains the same after a price change. A price increase, for instance, leads to a decrease in the quantity demanded that leaves the total expenditure on the good unchanged. Suppose, for example, that the total expenditure on first-run movies in Berkeley, California, is $5.4 million per year, regardless of the price of a movie ticket. For all points along the demand curve, the price times the quantity will be $5.4 million. If the price is $6, the quantity will be 900,000 tickets; if the price increases to $9, the quantity will drop to 600,000 tickets, as shown in Figure 4.11.

Table 4.3 summarizes the relationship between elasticity and expenditure. It is useful to review this table from the perspective of the seller of the good rather than the buyer. (What the seller perceives as total revenue, the consumer views as total expenditures.) When demand is inelastic, a price increase leads only to a

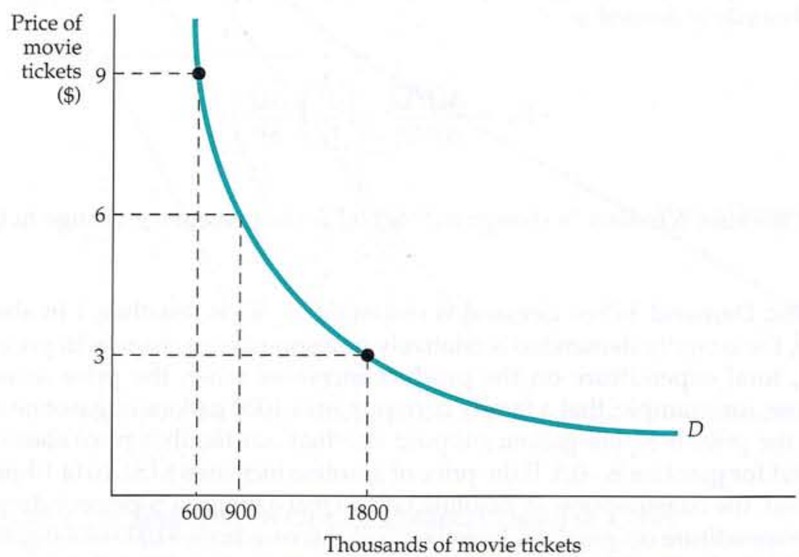

FIGURE 4.11 Unit-Elastic Demand Curve

When the price elasticity of demand is –1.0 at every price, the total expenditure is constant along the demand curve *D*.

TABLE 4.3 Price Elasticity and Consumer Expenditures

Demand	If Price Increases, Expenditures	If Price Decreases, Expenditures
Inelastic	Increase	Decrease
Unit elastic	Are unchanged	Are unchanged
Elastic	Decrease	Increase

small decrease in quantity demanded; thus, the seller's total revenue increases. But when demand is elastic, a price increase leads to a large decline in quantity demanded and total revenue falls.

EXAMPLE 4.3 The Aggregate Demand for Wheat

In Chapter 2 (Example 2.5—page 38), we explained that the demand for U.S. wheat has two components: domestic demand (by U.S. consumers) and export demand (by foreign consumers). Let's see how the total demand for wheat during 2007 can be obtained by aggregating the domestic and foreign demands.

Domestic demand for wheat is given by the equation

$$Q_{DD} = 1430 - 55P$$

where Q_{DD} is the number of bushels (in millions) demanded domestically, and P is the price in dollars per bushel. Export demand is given by

$$Q_{DE} = 1470 - 70P$$

where Q_{DE} is the number of bushels (in millions) demanded from abroad. As shown in Figure 4.12, domestic demand, given by *AB*, is relatively price inelastic. (Statistical studies have shown that price elasticity of domestic demand is about −0.2 to −0.3.) However, export demand, given by *CD*, is more price elastic, with an elasticity of about −0.4. Why? Export demand is more elastic than domestic demand because poorer countries that import U.S. wheat turn to other grains and foodstuffs if wheat prices rise.[3]

To obtain the world demand for wheat, we set the left side of each demand equation equal to the quantity of wheat (the variable on the horizontal axis). We then add the right side of the equations, obtaining

$$Q_{DD} + Q_{DE} = (1430 - 55P) + (1470 - 70P) = 2900 - 125P$$

This generates the line segment *EF* in Figure 4.12.

At all prices above point C, however, there is no export demand, so that world demand and domestic demand are identical. As a result, for all prices above C, world demand is given by line segment *AE*. (If we were to add Q_{DE} for prices above C, we would be incorrectly adding a negative export demand to a positive domestic demand.) As the figure shows, the resulting total demand for wheat, given by *AEF*, is kinked. The kink occurs at point *E*, the price level above which there is no export demand.

[3]For a survey of statistical studies of demand and supply elasticities and an analysis of the U.S. wheat market, see Larry Salathe and Sudchada Langley, "An Empirical Analysis of Alternative Export Subsidy Programs for U.S. Wheat," *Agricultural Economics Research* 38, No. 1 (Winter 1986).

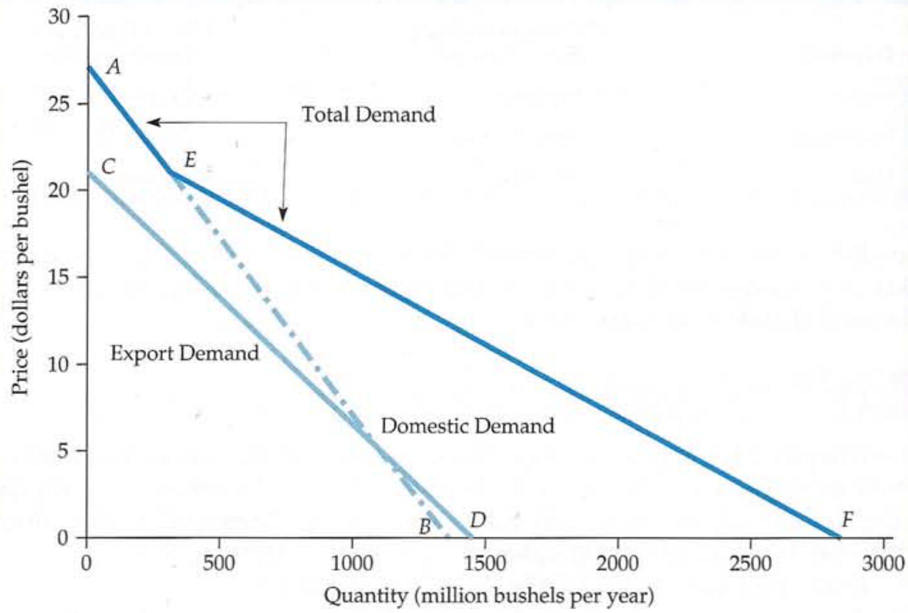

FIGURE 4.12 The Aggregate Demand for Wheat

The total world demand for wheat is the horizontal sum of the domestic demand *AB* and the export demand *CD*. Even though each individual demand curve is linear, the market demand curve is kinked, reflecting the fact that there is no export demand when the price of wheat is greater than about $21 per bushel.

EXAMPLE 4.4 The Demand for Housing

Housing is typically the most important single expenditure in a household's budget—on average, households spend 25 percent of their income on housing. A family's demand for housing depends on the age and status of the household making the purchasing decision. One approach to the housing demand is to relate the number of rooms per house for each household (the quantity demanded) both to an estimate of the price of an additional room in a house and to the household's family income. (Prices of rooms vary because of differences in construction costs, including the price of land.) Table 4.4 lists price and income elasticities for different demographic groups.

Elasticities show that the size of houses that consumers demand (as measured by the number of rooms) is relatively insensitive to either income or price. However, there are significant differences among subgroups of the population. For example, families with young household heads have a price elasticity of –0.25, which is more price elastic than the demands of families with older household heads. Presumably, families buying houses are more price sensitive when parents and their children are younger and there may be plans for more children. Among married households, the income elasticity of demand for rooms also increases with age, which tells us that older households buy larger houses than younger households.

TABLE 4.4 Price and Income Elasticities of the Demand for Rooms

Group	Price Elasticity	Income Elasticity
Single individuals	−0.10	0.21
Married, head of household age less than 30, 1 child	−0.25	0.06
Married, head age 30–39, 2 or more children	−0.15	0.12
Married, head age 50 or older, 1 child	−0.08	0.19

Price and income elasticities of demand for housing also depend on where people live.[4] Demand in central cities is much more price elastic than in suburbs. Income elasticities, however, increase as one moves farther from the central city. Thus poorer (on average) central-city residents (who live where the price of land is relatively high) are more price sensitive in their housing choices than their wealthier suburban counterparts.

For poor families, the fraction of income spent on housing is large. For instance, renters with an income in the bottom 20 percent of the income distribution spend roughly 55 percent of their income on housing.[5] Many government programs, such as subsidies, rent controls, and land-use regulations, have been proposed to shape the housing market in ways that might ease the housing burden on the poor.

How effective are income subsidies? To answer this, we need to know the income elasticity of demand for housing for low-income households. If the subsidy increases the demand for housing substantially, then we can presume that the subsidy will lead to improved housing for the poor.[6] On the other hand, if the extra money were spent on items other than housing, the subsidy, while perhaps still beneficial, will have failed to address policy concerns related to housing.

The evidence indicates that for poor households (with incomes in the bottom tenth percentile of all households), the income elasticity of housing is only about 0.09, which implies that income subsidies would be spent primarily on items other than housing. By comparison, the income elasticity for housing among the wealthiest households (the top 10 percent) is about 0.54.

[4]See Allen C. Goodman and Masahiro Kawai, "Functional Form, Sample Selection, and Housing Demand," *Journal of Urban Economics* 2 (September 1986): 155–67. Also see Paul Cheshire and Stephen Sheppard, "Estimating the Demand for Housing, Land, and Neighborhood Characteristics," *Oxford Bulletin of Economics and Statistics*, 60 (1998): 357–82.

[5]This is the starting point of the "affordable" housing debate. For an overview, see John Quigley and Steven Raphael, "Is Housing Unaffordable? Why Isn't It More Affordable," *Journal of Economic Perspectives* 18 (2004): 191–214.

[6]Julia L. Hansen, John P. Formby, and W. James Smith, "Estimating the Income Elasticity of Demand for Housing: A Comparison of Traditional and Lorenz-Concentration Curve Methodologies," *Journal of Housing Economics* 7 (1998): 328–42.

4.4 CONSUMER SURPLUS

• **consumer surplus** Difference between what a consumer is willing to pay for a good and the amount actually paid.

Consumers buy goods because the purchase makes them better off. **Consumer surplus** measures *how much* better off individuals are, in the aggregate, because they can buy goods in the market. Because different consumers place different values on the consumption of particular goods, the maximum amount they are willing to pay for those goods also differs. *Individual consumer surplus is the difference between the maximum amount that a consumer is willing to pay for a good and the amount that the consumer actually pays.* Suppose, for example, that a student would have been willing to pay \$13 for a rock concert ticket even though she only had to pay \$12. The \$1 difference is her consumer surplus.[7] When we add the consumer surpluses of all consumers who buy a good, we obtain a measure of the *aggregate* consumer surplus.

Consumer Surplus and Demand

Consumer surplus can be calculated easily if we know the demand curve. To see the relationship between demand and consumer surplus, let's examine the individual demand curve for concert tickets shown in Figure 4.13. (Although the following discussion applies to this particular individual demand curve, a similar argument also applies to a market demand curve.) Drawing the demand

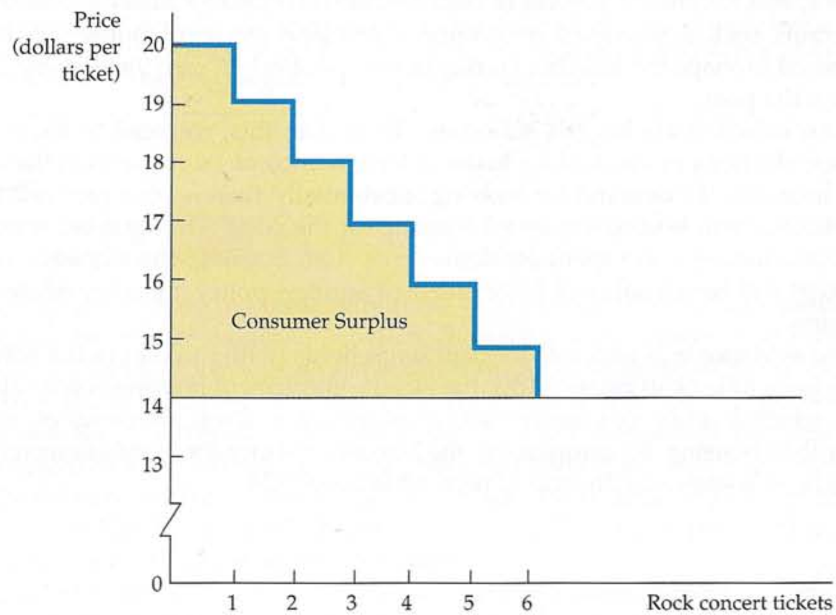

FIGURE 4.13 Consumer Surplus

Consumer surplus is the total benefit from the consumption of a product, less the total cost of purchasing it. Here, the consumer surplus associated with six concert tickets (purchased at \$14 per ticket) is given by the yellow-shaded area.

[7]Measuring consumer surplus in dollars involves an implicit assumption about the shape of consumers' indifference curves: namely, that the marginal utility associated with increases in a consumer's income remains constant within the range of income in question. In many cases, this is a reasonable assumption. It may be suspect, however, when large changes in income are involved.

curve as a staircase rather than a straight line shows us how to measure the value that our consumer obtains from buying different numbers of tickets.

When deciding how many tickets to buy, our student might reason as follows: The first ticket costs \$14 but is worth \$20. This \$20 valuation is obtained by using the demand curve to find the maximum amount that she will pay for each *additional* ticket (\$20 being the maximum that she will pay for the *first* ticket). The first ticket is worth purchasing because it generates \$6 of surplus value above and beyond its cost. The second ticket is also worth buying because it generates a surplus of \$5 (\$19 – \$14). The third ticket generates a surplus of \$4. The fourth, however, generates a surplus of only \$3, the fifth a surplus of \$2, and the sixth a surplus of just \$1. Our student is indifferent about purchasing the seventh ticket (which generates zero surplus) and prefers not to buy any more than that because the value of each additional ticket is less than its cost. In Figure 4.13, consumer surplus is found by *adding the excess values or surpluses for all units purchased*. In this case, then, consumer surplus equals

$$\$6 + \$5 + \$4 + \$3 + \$2 + \$1 = \$21$$

To calculate the aggregate consumer surplus in a market, we simply find the area below the *market* demand curve and above the price line. For our rock concert example, this principle is illustrated in Figure 4.14. Now, because the number of tickets sold is measured in thousands and individuals' demand curves differ, the market demand curve appears as a straight line. Note that the

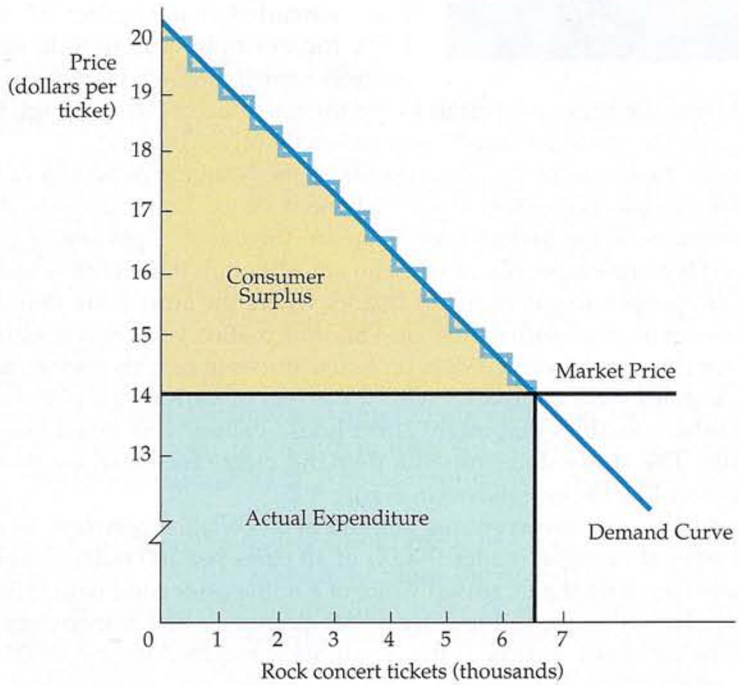

FIGURE 4.14 Consumer Surplus Generalized

For the market as a whole, consumer surplus is measured by the area under the demand curve and above the line representing the purchase price of the good. Here, the consumer surplus is given by the yellow-shaded triangle and is equal to $1/2 \times (\$20 - \$14) \times 6500 = \$19{,}500$.

actual expenditure on tickets is $6500 \times \$14 = \$91{,}000$. Consumer surplus, shown as the yellow-shaded triangle, is

$$1/2 \times (\$20 - \$14) \times 6500 = \$19{,}500$$

This amount is the total benefit to consumers, less what they paid for the tickets.

Of course, market demand curves are not always straight lines. Nonetheless, we can always measure consumer surplus by finding the area below the demand curve and above the price line.

Applying Consumer Surplus Consumer surplus has important applications in economics. When added over many individuals, it measures the aggregate benefit that consumers obtain from buying goods in a market. When we combine consumer surplus with the aggregate profits that producers obtain, we can evaluate both the costs and benefits not only of alternative market structures, but of public policies that alter the behavior of consumers and firms in those markets.

EXAMPLE 4.5 The Value of Clean Air

Air is free in the sense that we don't pay to breathe it. But the absence of a market for air may help explain why the air quality in some cities has been deteriorating for decades. To encourage cleaner air, Congress passed the Clean Air Act in 1977 and has since amended it a number of times. In 1990, for example, automobile emissions controls were tightened. Were these controls worth it? Were the benefits of cleaning up the air sufficient to outweigh the costs imposed directly on car producers and indirectly on car buyers?

To answer these questions, Congress asked the National Academy of Sciences to evaluate emissions controls in a cost-benefit study. Using empirically determined estimates of the demand for clean air, the benefits portion of the study determined how much people value clean air. Although there is no actual market for clean air, people do pay more for houses where the air is clean than for comparable houses in areas with dirtier air. This information was used to estimate the demand for clean air.[8] Detailed data on house prices in neighborhoods of Boston and Los Angeles were compared with the levels of various air pollutants. The effects of other variables that might affect house values were taken into account statistically. The study determined a demand curve for clean air that looked approximately like the one shown in Figure 4.15.

The horizontal axis measures the amount of *air pollution reduction*, as exemplified by a level of nitrogen oxides (NOX) of 10 parts per 100 million (pphm); the vertical axis measures the increased value of a home associated with those reductions. Consider, for example, the demand for cleaner air of a homeowner in a city in which the air is rather dirty. If the family were required to pay \$1000 for each 1 pphm reduction in air pollution, it would choose *A* on the demand curve in order to obtain a pollution reduction of 5 pphm.

[8]The results are summarized in Daniel L. Rubinfeld, "Market Approaches to the Measurement of the Benefits of Air Pollution Abatement," in Ann Friedlaender, ed., *The Benefits and Costs of Cleaning the Air* (Cambridge: MIT Press, 1976), 240–73.

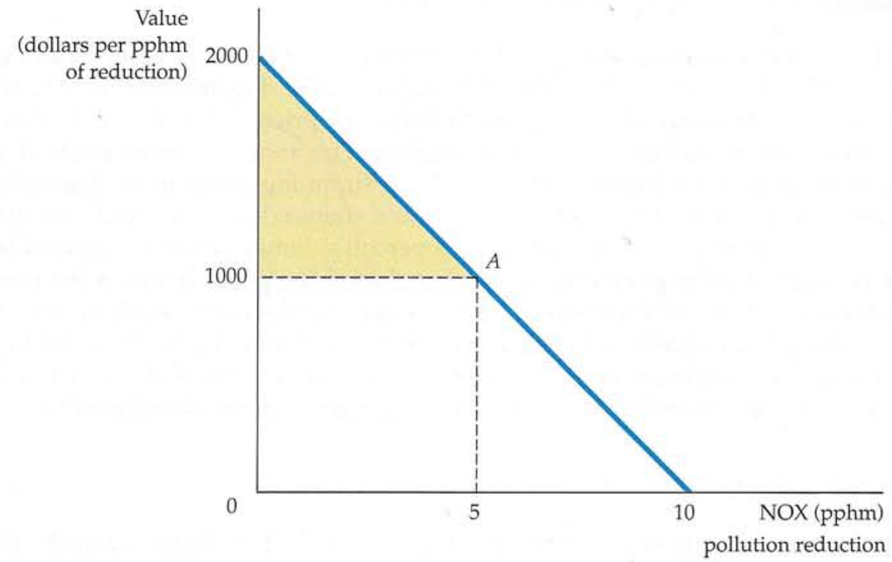

FIGURE 4.15 Valuing Cleaner Air

The yellow-shaded triangle gives the consumer surplus generated when air pollution is reduced by 5 parts per 100 million of nitrogen oxide at a cost of $1000 per part reduced. The surplus is created because most consumers are willing to pay more than $1000 for each unit reduction of nitrogen oxide.

How much is a 50-percent, or 5-pphm, reduction in pollution worth to this same family? We can measure this value by calculating the consumer surplus associated with reducing air pollution. Because the price for this reduction is $1000 per unit, the family would pay $5000. However, the family values all but the last unit of reduction by more than $1000. As a result, the yellow-shaded triangle in Figure 4.15 gives the value of the cleanup (above and beyond the payment). Because the demand curve is a straight line, the surplus can be calculated from the area of the triangle whose height is $1000 ($2000 – $1000) and whose base is 5 pphm. Therefore, the value to the household of the nitrogen oxide pollution reduction is $2500.

A more recent study that focused on suspended participates also found that households place substantial value on air pollution reduction.[9] A one-milligram per cubic meter reduction in total suspended particulates (from a mean of about 60 milligrams per cubic meter) was valued at $2,400 per household.

A complete cost-benefit analysis would use a measure of the total benefit of the cleanup—the benefit per household times the number of households. This figure could be compared with the total cost of the cleanup to determine whether such a project was worthwhile. We will discuss clean air further in Chapter 18, when we describe the tradeable emissions permits that were introduced by the Clean Air Act Amendments of 1990.

[9]Kenneth Y. Chay and Michael Greenstone, "Does Air Quality Matter? Evidence from the Housing Market," *Journal of Political Economy* 113 (2005): 376–424.

4.5 NETWORK EXTERNALITIES

So far, we have assumed that people's demands for a good are independent of one another. In other words, Tom's demand for coffee depends on Tom's tastes and income, the price of coffee, and perhaps the price of tea. But it does not depend on Dick's or Harry's demand for coffee. This assumption has enabled us to obtain the market demand curve simply by summing individuals' demands.

For some goods, however, one person's demand also depends on the demands of *other* people. In particular, a person's demand may be affected by the number of other people who have purchased the good. If this is the case, there exists a **network externality**. Network externalities can be positive or negative. A *positive* network externality exists *if the quantity of a good demanded by a typical consumer increases in response to the growth in purchases of other consumers.* If the quantity demanded decreases, there is a *negative* network externality.

• **network externality** Situation in which each individual's demand depends on the purchases of other individuals.

The Bandwagon Effect

• **bandwagon effect** Positive network externality in which a consumer wishes to possess a good in part because others do.

One example of a positive network externality is the **bandwagon effect**—the desire to be in style, to possess a good because almost everyone else has it, or to indulge in a fad. The bandwagon effect often arises with children's toys (Nintendo video games, for example). In fact, exploiting this effect is a major objective in marketing and advertising toys. Often it is also the key to success in selling clothing.

The bandwagon effect is illustrated in Figure 4.16, in which the horizontal axis measures the sales of some fashionable good in thousands per month. Suppose consumers think that only 20,000 people have bought a certain good. Because this is a small number relative to the total population, consumers will have little motivation to buy the good in order to be in style. Some consumers may still buy it (depending on price), but only for its intrinsic value. In this case, demand is given by the curve D_{20}. (This hypothetical demand curve assumes that there are no externalities.)

Suppose instead that consumers think that 40,000 people have bought the good. Now they find the good more attractive and want to buy more. The demand curve is D_{40}, which is to the right of D_{20}. Similarly, if consumers think that 60,000 people have bought the good, the demand curve will be D_{60}, and so on. The more people consumers believe to have bought the good, the farther to the right the demand curve shifts.

Ultimately, consumers will get a good sense of how many people have in fact purchased a good. This number will depend, of course, on its price. In Figure 4.16, for example, we see that if the price were \$30, 40,000 people would buy the good. Thus the relevant demand curve would be D_{40}. If the price were \$20, 80,000 people would buy the good and the relevant demand curve would be D_{80}. *The market demand curve is therefore found by joining the points on the curves D_{20}, D_{40}, D_{60}, D_{80}, and D_{100} that correspond to the quantities 20,000, 40,000, 60,000, 80,000 and 100,000.*

Compared with the curves D_{20}, etc., the market demand curve is relatively elastic. To see why the bandwagon effect leads to a more elastic demand curve, consider the effect of a drop in price from \$30 to \$20, with a demand curve of D_{40}. If there were no bandwagon effect, quantity demanded would increase from 40,000 to only 48,000. But as more people buy the good and it becomes stylish to own it, the bandwagon effect increases quantity demanded further, to 80,000. Thus, the bandwagon effect increases the response of demand to price

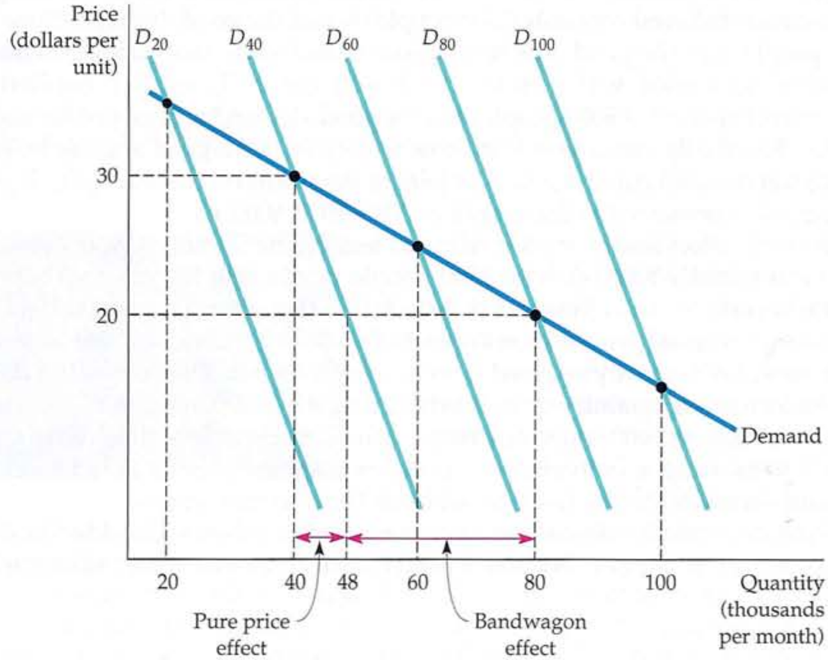

FIGURE 4.16 Positive Network Externality: Bandwagon Effect

A bandwagon effect is a positive network externality in which the quantity of a good that an individual demands grows in response to the growth of purchases by other individuals. Here, as the price of the product falls from \$30 to \$20, the bandwagon effect causes the demand for the good to shift to the right, from D_{40} to D_{80}.

changes—i.e., it makes demand more elastic. As we'll see later, this result has important implications for producers' pricing strategies.

Although the bandwagon effect is associated with fads and stylishness, positive network externalities can arise for other reasons. The greater the number of people who own a particular good, the greater the intrinsic value of that good to each owner. For example, if I am the only person to own a compact disc player, it will not be economical for companies to manufacture compact discs; without the discs, the CD player will obviously be of little value to me. But the greater the number of people who own players, the more discs will be manufactured and the greater will be the value of the player to me. The same is true for personal computers: The more people who own them, the more software will be written, and thus the more useful computers will be to people who own them.

The Snob Effect

Network externalities are sometimes negative. Consider the **snob effect**, which refers to the desire to own exclusive or unique goods. The quantity demanded of a "snob good" is higher the *fewer* the people who own it. Rare works of art, specially designed sports cars, and made-to-order clothing are snob goods. The value one gets from a painting or a sports car is partly the prestige, status, and exclusivity resulting from the fact that few other people own one like it.

• **snob effect** Negative network externality in which a consumer wishes to own an exclusive or unique good.

Figure 4.17 illustrates the snob effect. D_2 is the demand curve that would apply if consumers believed that only 2000 people owned the good. If they believe that 4000 people own the good, it is less exclusive, and so its snob value is reduced. Quantity demanded will therefore be lower; curve D_4 applies. Similarly, if consumers believe that 6000 people own the good, demand is even smaller and D_6 applies. Eventually, consumers learn how widely owned a good actually is. Thus, the market demand curve is found by joining the points on curves D_2, D_4, D_6, etc., that actually correspond to the quantities 2000, 4000, 6000, etc.

The snob effect makes market demand less elastic. To see why, suppose the price was initially \$30,000, with 2000 people purchasing the good. What happens when the price is lowered to \$15,000? If there were no snob effect, the quantity purchased would increase to 14,000 (along curve D_2). But as a snob good, its value is greatly reduced if more people own it. The snob effect dampens the increase in quantity demanded, cutting it by 8000 units; the net increase in sales is only to 6000 units. For many goods, marketing and advertising are geared to creating a snob effect (e.g., Rolex watches). The goal is less elastic demand—a result that makes it possible for firms to raise prices.

Negative network externalities can arise for other reasons. Consider the effect of congestion in queues. Because I prefer short lines and fewer skiers on the

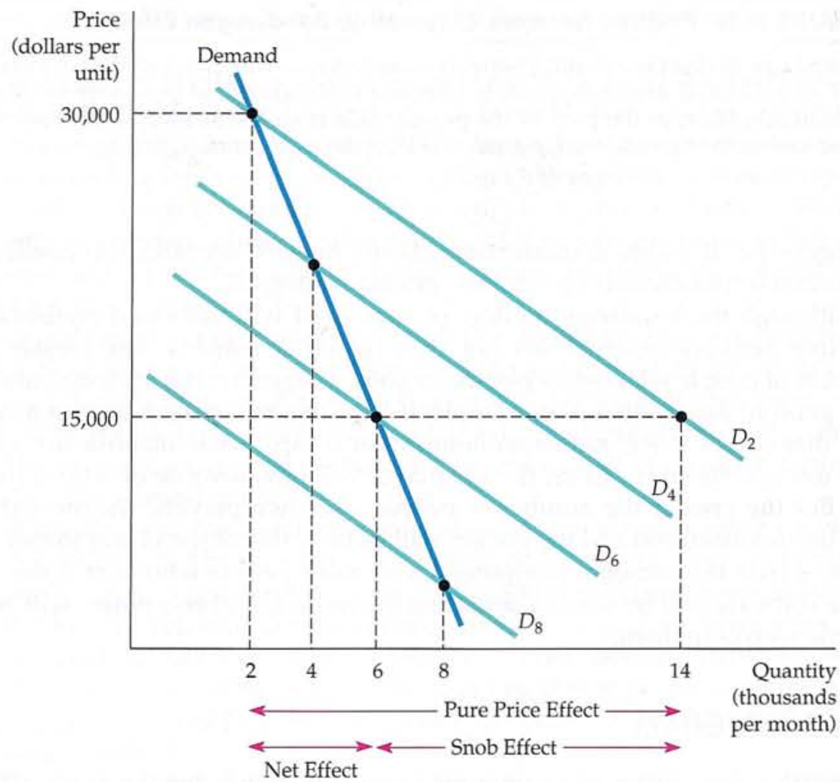

FIGURE 4.17 Negative Network Externality: Snob Effect

The snob effect is a negative network externality in which the quantity of a good that an individual demands falls in response to the growth of purchases by other individuals. Here, as the price falls from \$30,000 to \$15,000 and more people buy the good, the snob effect causes the demand for the good to shift to the left, from D_2 to D_6.

slopes, the value I obtain from a lift ticket at a ski resort is lower the more people there are who have bought tickets. Likewise for entry to an amusement park, skating rink, or beach.[10]

EXAMPLE 4.6 Network Externalities and the Demands for Computers and E-Mail

The 1950s and 1960s witnessed phenomenal growth in the demand for mainframe computers. From 1954 to 1965, for example, annual revenues from the leasing of mainframes increased at the extraordinary rate of 78 percent per year, while prices declined by 20 percent per year. Granted, prices were falling and the quality of computers was also increasing dramatically, but to account for this kind of growth, the elasticity of demand would have to be quite large. IBM, among other computer manufacturers, wanted to know what was going on.

An econometric study by Gregory Chow helped provide some answers.[11] Chow found that the demand for computers follows a "saturation curve"—a dynamic process whereby demand, though small at first, grows slowly. Soon, however, it grows rapidly, until finally nearly everyone likely to buy a product has done so, whereby the market becomes saturated. This rapid growth occurs because of a positive network externality: As more and more organizations own computers, as more and better software is written, and as more people are trained to use computers, the value of having a computer increases. Because this process causes demand to increase, still more software and better trained users are needed, and so on.

This network externality was an important part of the demand for computers. Chow found that it could account for nearly half the rapid growth of computer use between 1954 and 1965. Reductions in the inflation-adjusted price (he found a price elasticity of demand for computers of -1.44) and major increases in power and quality, which also made computers much more useful and effective, accounted for the other half. Other studies have shown that this process continued through the following decades.[12] In fact, this same kind of network externality helped to fuel a rapid growth rate in the demand for personal computers.

Today there is little debate about the importance of network externalities as an explanation for the success of Microsoft's Windows PC operating system, which by 2008 was being used in about 90 percent of personal computers worldwide. At least as significant has been the phenomenal success of the Microsoft Office Suite of PC applications (which includes Word and Excel). In 2008, Microsoft Office enjoyed well over 90 percent of the market.

Network externalities are, of course, not limited to computers. Consider the explosive growth in Internet usage, particularly the use of e-mail and instant

[10]Tastes, of course, differ. Some people associate a *positive* network externality with skiing or a day on the beach; they enjoy crowds and may even find the slope or beach lonely without them.

[11]See Gregory Chow, "Technological Change and the Demand for Computers," *American Economic Review* 57: 5 (December 1967): 1117–30.

[12]See Robert J. Gordon, "The Postwar Evolution of Computer Prices," in Dale W. Jorgenson and Ralph Landau, eds., *Technology and Capital Formation* (Cambridge: MIT Press, 1989).

messaging. Use of the Internet has grown at 20 percent per year since 1998, and as of 2002, over 55 percent of the U.S. population was connected. Clearly a strong positive network externality is at work. Because e-mail can only be transmitted to another e-mail user, the value of using e-mail depends crucially on how many other people use it. By 2002, nearly 50 percent of the U.S. population claimed to use e-mail, up from 35 percent in 2000.

Like e-mail, instant messaging enables one computer to communicate directly with another. Unlike e-mail, however, instant messaging simulates a real-time conversation. Again, a positive network externality is present because both parties must be using compatible software. Many Internet service providers, such as America Online (AOL) and Microsoft Network (MSN), offer free instant messaging to both their customers and the online public. By offering the service for free, they hope to capitalize on this positive network externality to promote use of other software.

*4.6 EMPIRICAL ESTIMATION OF DEMAND

Later in this book, we will explain how demand information is used as input into a firm's economic decision-making process. General Motors, for example, must understand automobile demand to decide whether to offer rebates or below-market-rate loans for new cars. Knowledge about demand is also important for public policy decisions. Understanding the demand for oil, for instance, can help Congress decide whether to pass an oil import tax. You may wonder how it is that economists determine the shape of demand curves and how price and income elasticities of demand are actually calculated. In this starred section, we will briefly examine some methods for evaluating and forecasting demand. The section is starred not only because the material is more advanced, but also because it is not essential for much of the later analysis in the book. Nonetheless, this material is instructive and will help you appreciate the empirical foundation of the theory of consumer behavior. The basic statistical tools for estimating demand curves and demand elasticities are described in the appendix to this book, entitled "The Basics of Regression."

The Statistical Approach to Demand Estimation

Firms often rely on market information based on actual studies of demand. Properly applied, the statistical approach to demand estimation can help researchers sort out the effects of variables, such as income and the prices of other products, on the quantity of a product demanded. Here we outline some of the conceptual issues involved in the statistical approach.

Table 4.5 shows the quantity of raspberries sold in a market each year. Information about the market demand for raspberries would be valuable to an organization representing growers because it would allow them to predict sales on the basis of their own estimates of price and other demand-determining variables. Let's suppose that, focusing on demand, researchers find that the quantity of raspberries produced is sensitive to weather conditions but not to the current market price (because farmers make their planting decisions based on last year's price).

The price and quantity data from Table 4.5 are graphed in Figure 4.18. If we believe that price alone determines demand, it would be plausible to describe

TABLE 4.5 Demand Data

Year	Quantity (Q)	Price (P)	Income (I)
1995	4	24	10
1996	7	20	10
1997	8	17	10
1998	13	17	17
1999	16	10	17
2000	15	15	17
2001	19	12	20
2002	20	9	20
2003	22	5	20

the demand for the product by drawing a straight line (or other appropriate curve), $Q = a - bP$, which "fit" the points as shown by demand curve D. (The "least-squares" method of curve-fitting is described in the appendix to the book.)

Does curve D (given by the equation $Q = 28.2 - 1.00P$) really represent the demand for the product? The answer is yes—but only if no important factors other than price affect demand. In Table 4.5, however, we have included data for one other variable: the average income of purchasers of the product. Note that income (I) has increased twice during the study, suggesting that the demand curve has shifted twice. Thus demand curves d_1, d_2, and d_3 in Figure 4.18 give a

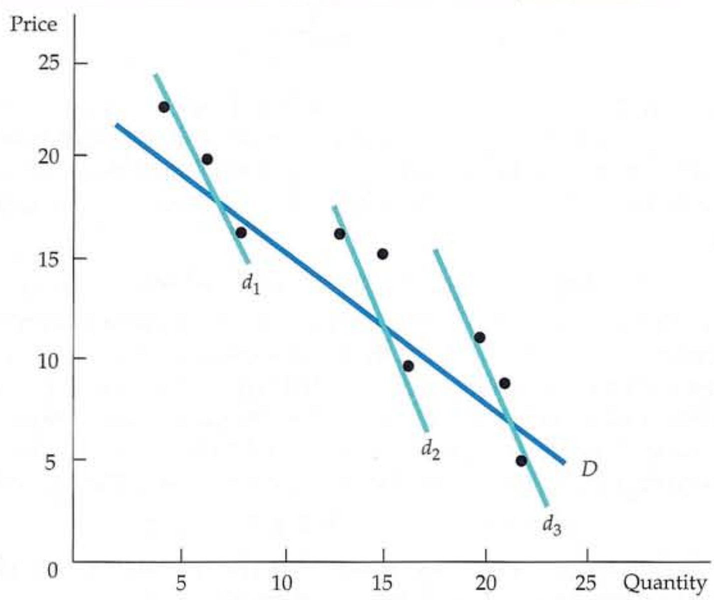

FIGURE 4.18 Estimating Demand

Price and quantity data can be used to determine the form of a demand relationship. But the same data could describe a single demand curve D or three demand curves d_1, d_2, and d_3 that shift over time.

more likely description of demand. This *linear demand curve* would be described algebraically as

$$Q = a - bP + cI \tag{4.2}$$

The income term in the demand equation allows the demand curve to shift in a parallel fashion as income changes. The demand relationship, calculated using the least-squares method, is given by $Q = 8.08 - .49P + .81I$.

The Form of the Demand Relationship

Because the demand relationships discussed above are straight lines, the effect of a change in price on quantity demanded is constant. However, the price elasticity of demand varies with the price level. For the demand equation $Q = a - bP$, for example, the price elasticity E_P is

$$E_P = (\Delta Q/\Delta P)(P/Q) = -b(P/Q) \tag{4.3}$$

Thus elasticity increases in magnitude as the price increases (and the quantity demanded falls).

Consider, for example, the linear demand for raspberries, which was estimated to be $Q = 8.08 - .49P + .81I$. The elasticity of demand in 1999 (when $Q = 16$ and $P = 10$) is equal to $-.49\ (10/16) = -.31$, whereas the elasticity in 2003 (when $Q = 22$ and $P = 5$) is substantially lower: $-.11$.

There is no reason to expect elasticities of demand to be constant. Nevertheless, we often find it useful to work with the *isoelastic demand curve*, in which the price elasticity and the income elasticity are constant. When written in its *log-linear form*, the isoelastic demand curve appears as follows:

$$\log(Q) = a - b\log(P) + c\log(I) \tag{4.4}$$

where log ( ) is the logarithmic function and a, b, and c are the constants in the demand equation. The appeal of the log-linear demand relationship is that the slope of the line $-b$ is the price elasticity of demand and the constant c is the income elasticity.[13] Using the data in Table 4.5, for example, we obtained the regression line

$$\log(Q) = -0.23 - 0.34\log(P) + 1.33\log(I)$$

This relationship tells us that the price elasticity of demand for raspberries is -0.34 (that is, demand is inelastic), and that the income elasticity is 1.33.

We have seen that it can be useful to distinguish between goods that are complements and goods that are substitutes. Suppose that P_2 represents the price of a second good—one which is believed to be related to the product we are studying. We can then write the demand function in the following form:

$$\log(Q) = a - b\log(P) + b_2\log(P_2) + c\log(I)$$

When b_2, the cross-price elasticity, is positive, the two goods are substitutes; when b_2 is negative, the two goods are complements.

[13]The natural logarithmic function with base e has the property that $\Delta(\log(Q)) = \Delta Q/Q$ for any change in $\log(Q)$. Similarly, $\Delta(\log(P)) = \Delta P/P$ for any change in $\log(P)$. It follows that $\Delta(\log(Q)) = \Delta Q/Q = -b[\Delta(\log(P))] = -b(\Delta P/P)$. Therefore, $(\Delta Q/Q)/(\Delta P/P) = -b$, which is the price elasticity of demand. By a similar argument, the income elasticity of demand c is given by $(\Delta Q/Q)/(\Delta I/I)$.

The specification and estimation of demand curves has been a rapidly growing endeavor, not only in marketing, but also in antitrust analyses. It is now commonplace to use estimated demand relationships to evaluate the likely effects of mergers.[14] What were once prohibitively costly analyses involving mainframe computers can now be carried out in a few seconds on a personal computer. Accordingly, governmental competition authorities and economic and marketing experts in the private sector make frequent use of supermarket scanner data as inputs for estimating demand relationships. Once the price elasticity of demand for a particular product is known, a firm can decide whether it is profitable to raise or lower price. Other things being equal, the lower in magnitude the elasticity, the more likely the profitability of a price increase.

EXAMPLE 4.7 The Demand for Ready-to-Eat Cereal

The Post Cereals division of Kraft General Foods acquired the Shredded Wheat cereals of Nabisco in 1995. The acquisition raised the legal and economic question of whether Post would raise the price of its best-selling brand, Grape Nuts, or the price of Nabisco's most successful brand, Shredded Wheat Spoon Size.[15] One important issue in a lawsuit brought by the state of New York was whether the two brands were close substitutes for one another. If so, it would be more profitable for Post to increase the price of Grape Nuts (or Shredded Wheat) *after* rather than *before* the acquisition. Why? Because after the acquisition the lost sales from consumers who switched away from Grape Nuts (or Shredded Wheat) would be recovered to the extent that they switched to the substitute product.

The extent to which a price increase will cause consumers to switch is given (in part) by the price elasticity of demand for Grape Nuts. Other things being equal, the higher the demand elasticity, the greater the loss of sales associated with a price increase. The more likely, too, that the price increase will be unprofitable.

The substitutability of Grape Nuts and Shredded Wheat can be measured by the cross-price elasticity of demand for Grape Nuts with respect to the price of Shredded Wheat. The relevant elasticities were calculated using weekly data obtained from supermarket scanning of household purchases for 10 cities over a three-year period. One of the estimated isoelastic demand equations appeared in the following log-linear form:

$$\log(Q_{GN}) = 1.998 - 2.085 \log(P_{GN}) + 0.62 \log(I) + 0.14 \log(P_{SW})$$

where Q_{GN} is the amount (in pounds) of Grape Nuts sold weekly, P_{GN} the price per pound of Grape Nuts, I real personal income, and P_{SW} the price per pound of Shredded Wheat Spoon Size.

The demand for Grape Nuts is elastic (at current prices), with a price elasticity of about –2. The income elasticity is 0.62: In other words, increases in income

[14]See Jonathan B. Baker and Daniel L. Rubinfeld, "Empirical Methods in Antitrust Litigation: Review and Critique," *American Law and Economics Review*, 1(1999): 386–435.

[15]*State of New York v. Kraft General Foods, Inc.*, 926 F. Supp. 321, 356 (S.D.N.Y. 1995).

lead to increases in cereal purchases, but at less than a 1-for-1 rate. Finally, the cross-price elasticity is 0.14. This figure is consistent with the fact that although the two cereals are substitutes (the quantity demanded of Grape Nuts increases in response to an increase in the price of Shredded Wheat), they are not very close substitutes.

Interview and Experimental Approaches to Demand Determination

Another way to obtain information about demand is through *interviews* in which consumers are asked how much of a product they might be willing to buy at a given price. This approach, however, may not succeed when people lack information or interest or even want to mislead the interviewer. Therefore, market researchers have designed various indirect survey techniques. Consumers might be asked, for example, what their current consumption behavior is and how they would respond if a certain product were available at, say, a 10-percent discount. They might be asked how they would expect others to behave. Although indirect approaches to demand estimation can be fruitful, the difficulties of the interview approach have forced economists and marketing specialists to look to alternative methods.

In *direct marketing experiments*, actual sales offers are posed to potential customers. An airline, for example, might offer a reduced price on certain flights for six months, partly to learn how the price change affects demand for flights and partly to learn how competitors will respond. Alternatively, a cereal company might test market a new brand in Buffalo, New York, and Omaha, Nebraska, with some potential customers being given coupons ranging in value from 25 cents to $1 per box. The response to the coupon offer tells the company the shape of the underlying demand curve, helping the marketers decide whether to market the product nationally and internationally, and at what price.

Direct experiments are real, not hypothetical, but even so, problems remain. The wrong experiment can be costly, and even if profits and sales rise, the firm cannot be entirely sure that these increases resulted from the experimental change; other factors probably changed at the same time. Moreover, the response to experiments—which consumers often recognize as short-lived—may differ from the response to permanent changes. Finally, a firm can afford to try only a limited number of experiments.

SUMMARY

1. Individual consumers' demand curves for a commodity can be derived from information about their tastes for all goods and services and from their budget constraints.
2. Engel curves, which describe the relationship between the quantity of a good consumed and income, can be useful in showing how consumer expenditures vary with income.
3. Two goods are substitutes if an increase in the price of one leads to an increase in the quantity demanded of the other. In contrast, two goods are complements if an increase in the price of one leads to a decrease in the quantity demanded of the other.
4. The effect of a price change on the quantity demanded of a good can be broken into two parts: a substitution effect, in which the level of utility remains constant while price changes, and an income effect, in which the price remains constant while the level of utility changes. Because the income effect can be positive or negative, a price change can have a small or a large effect on quantity demanded. In the unusual case of a

so-called Giffen good, the quantity demanded may move in the same direction as the price change, thereby generating an upward-sloping individual demand curve.

5. The market demand curve is the horizontal summation of the individual demand curves of all consumers in the market for a good. It can be used to calculate how much people value the consumption of particular goods and services.
6. Demand is price inelastic when a 1-percent increase in price leads to a less than 1-percent decrease in quantity demanded, thereby increasing the consumer's expenditure. Demand is price elastic when a 1-percent increase in price leads to a more than 1-percent decrease in quantity demanded, thereby decreasing the consumer's expenditure. Demand is unit elastic when a 1-percent increase in price leads to a 1-percent decrease in quantity demanded.
7. The concept of consumer surplus can be useful in determining the benefits that people receive from the consumption of a product. Consumer surplus is the difference between the maximum amount a consumer is willing to pay for a good and what he actually pays for it.
8. A network externality occurs when one person's demand is affected directly by the purchasing decisions of other consumers. A positive network externality, the bandwagon effect, occurs when a typical consumer's quantity demanded increases because she considers it stylish to buy a product that others have purchased. Conversely, a negative network externality, the snob effect, occurs when the quantity demanded increases because fewer people own the good.
9. A number of methods can be used to obtain information about consumer demand. These include interview and experimental approaches, direct marketing experiments, and the more indirect statistical approach. The statistical approach can be very powerful in its application, but it is necessary to determine the appropriate variables that affect demand before the statistical work is done.

QUESTIONS FOR REVIEW

1. Explain the difference between each of the following terms:
   a. a price consumption curve and a demand curve
   b. an individual demand curve and a market demand curve
   c. an Engel curve and a demand curve
   d. an income effect and a substitution effect
2. Suppose that an individual allocates his or her entire budget between two goods, food and clothing. Can both goods be inferior? Explain.
3. Explain whether the following statements are true or false:
   a. The marginal rate of substitution diminishes as an individual moves downward along the demand curve.
   b. The level of utility increases as an individual moves downward along the demand curve.
   c. Engel curves always slope upward.
4. Tickets to a rock concert sell for $10. But at that price, the demand is substantially greater than the available number of tickets. Is the value or marginal benefit of an additional ticket greater than, less than, or equal to $10? How might you determine that value?
5. Which of the following combinations of goods are complements and which are substitutes? Can they be either in different circumstances? Discuss.
   a. a mathematics class and an economics class
   b. tennis balls and a tennis racket
   c. steak and lobster
   d. a plane trip and a train trip to the same destination
   e. bacon and eggs
6. Suppose that a consumer spends a fixed amount of income per month on the following pairs of goods:
   a. tortilla chips and salsa
   b. tortilla chips and potato chips
   c. movie tickets and gourmet coffee
   d. travel by bus and travel by subway

   If the price of one of the goods increases, explain the effect on the quantity demanded of each of the goods. In each pair, which are likely to be complements and which are likely to be substitutes?
7. Which of the following events would cause a movement *along* the demand curve for U.S. produced clothing, and which would cause a *shift* in the demand curve?
   a. the removal of quotas on the importation of foreign clothes
   b. an increase in the income of U.S. citizens
   c. a cut in the industry's costs of producing domestic clothes that is passed on to the market in the form of lower prices
8. For which of the following goods is a price increase likely to lead to a substantial income (as well as substitution) effect?
   a. salt
   b. housing
   c. theater tickets
   d. food
9. Suppose that the average household in a state consumes 800 gallons of gasoline per year. A 20-cent gasoline tax is introduced, coupled with a $160 annual tax rebate per household. Will the household be better or worse off under the new program?

10. Which of the following three groups is likely to have the most, and which the least, price-elastic demand for membership in the Association of Business Economists?
    a. students
    b. junior executives
    c. senior executives
11. Explain which of the following items in each pair is more price elastic.
    a. The demand for a specific brand of toothpaste and the demand for toothpaste in general
    b. The demand for gasoline in the short run and the demand for gasoline in the long run
12. Explain the difference between a positive and a negative network externality and give an example of each.

EXERCISES

1. An individual sets aside a certain amount of his income per month to spend on his two hobbies, collecting wine and collecting books. Given the information below, illustrate both the price-consumption curve associated with changes in the price of wine and the demand curve for wine.

Price Wine	Price Book	Quantity Wine	Quantity Book	Budget
$10	$10	7	8	$150
$12	$10	5	9	$150
$15	$10	4	9	$150
$20	$10	2	11	$150

2. An individual consumes two goods, clothing and food. Given the information below, illustrate both the income-consumption curve and the Engel curve for clothing and food.

Price Clothing	Price Food	Quantity Clothing	Quantity Food	Income
$10	$2	6	20	$100
$10	$2	8	35	$150
$10	$2	11	45	$200
$10	$2	15	50	$250

3. Jane always gets twice as much utility from an extra ballet ticket as she does from an extra basketball ticket, regardless of how many tickets of either type she has. Draw Jane's income-consumption curve and her Engel curve for ballet tickets.
4. a. Orange juice and apple juice are known to be perfect substitutes. Draw the appropriate price-consumption curve (for a variable price of orange juice) and income-consumption curve.
   b. Left shoes and right shoes are perfect complements. Draw the appropriate price-consumption and income-consumption curves.
5. Each week, Bill, Mary, and Jane select the quantity of two goods, x_1 and x_2, that they will consume in order to maximize their respective utilities. They each spend their entire weekly income on these two goods.
   a. Suppose you are given the following information about the choices that Bill makes over a three-week period:

	x_1	x_2	P_1	P_2	I
Week 1	10	20	2	1	40
Week 2	7	19	3	1	40
Week 3	8	31	3	1	55

   Did Bill's utility increase or decrease between week 1 and week 2? Between week 1 and week 3? Explain using a graph to support your answer.
   b. Now consider the following information about the choices that Mary makes:

	x_1	x_2	P_1	P_2	I
Week 1	10	20	2	1	40
Week 2	6	14	2	2	40
Week 3	20	10	2	2	60

   Did Mary's utility increase or decrease between week 1 and week 3? Does Mary consider both goods to be normal goods? Explain.
   *c. Finally, examine the following information about Jane's choices:

	x_1	x_2	P_1	P_2	I
Week 1	12	24	2	1	48
Week 2	16	32	1	1	48
Week 3	12	24	1	1	36

   Draw a budget line-indifference curve graph that illustrates Jane's three chosen bundles. What can you say about Jane's preferences in this case? Identify the income and substitution effects that result from a change in the price of good x_1.
6. Two individuals, Sam and Barb, derive utility from the hours of leisure (L) they consume and from the amount of goods (G) they consume. In order to maximize utility,

they need to allocate the 24 hours in the day between leisure hours and work hours. Assume that all hours not spent working are leisure hours. The price of a good is equal to \$1 and the price of leisure is equal to the hourly wage. We observe the following information about the choices that the two individuals make:

		Sam	Barb	Sam	Barb
Price of G	Price of L	L (hours)	L (hours)	G (\$)	G (\$)
1	8	16	14	64	80
1	9	15	14	81	90
1	10	14	15	100	90
1	11	14	16	110	88

Graphically illustrate Sam's leisure demand curve and Barb's leisure demand curve. Place price on the vertical axis and leisure on the horizontal axis. Given that they both maximize utility, how can you explain the difference in their leisure demand curves?

7. The director of a theater company in a small college town is considering changing the way he prices tickets. He has hired an economic consulting firm to estimate the demand for tickets. The firm has classified people who go to the theater into two groups and has come up with two demand functions. The demand curves for the general public (Q_{gp}) and students (Q_s) are given below:

$$Q_{gp} = 500 - 5P$$
$$Q_s = 200 - 4P$$

   a. Graph the two demand curves on one graph, with P on the vertical axis and Q on the horizontal axis. If the current price of tickets is \$35, identify the quantity demanded by each group.
   b. Find the price elasticity of demand for each group at the current price and quantity.
   c. Is the director maximizing the revenue he collects from ticket sales by charging \$35 for each ticket? Explain.
   d. What price should he charge each group if he wants to maximize revenue collected from ticket sales?

8. Judy has decided to allocate exactly \$500 to college textbooks every year, even though she knows that the prices are likely to increase by 5 to 10 percent per year and that she will be getting a substantial monetary gift from her grandparents next year. What is Judy's price elasticity of demand for textbooks? Income elasticity?

9. The ACME Corporation determines that at current prices, the demand for its computer chips has a price elasticity of –2 in the short run, while the price elasticity for its disk drives is –1.
   a. If the corporation decides to raise the price of both products by 10 percent, what will happen to its sales? To its sales revenue?
   b. Can you tell from the available information which product will generate the most revenue? If yes, why? If not, what additional information do you need?

10. By observing an individual's behavior in the situations outlined below, determine the relevant income elasticities of demand for each good (i.e., whether it is normal or inferior). If you cannot determine the income elasticity, what additional information do you need?
   a. Bill spends all his income on books and coffee. He finds \$20 while rummaging through a used paperback bin at the bookstore. He immediately buys a new hardcover book of poetry.
   b. Bill loses \$10 he was going to use to buy a double espresso. He decides to sell his new book at a discount to a friend and use the money to buy coffee.
   c. Being bohemian becomes the latest teen fad. As a result, coffee and book prices rise by 25 percent. Bill lowers his consumption of both goods by the same percentage.
   d. Bill drops out of art school and gets an M.B.A. instead. He stops reading books and drinking coffee. Now he reads the *Wall Street Journal* and drinks bottled mineral water.

11. Suppose the income elasticity of demand for food is 0.5 and the price elasticity of demand is –1.0. Suppose also that Felicia spends \$10,000 a year on food, the price of food is \$2, and that her income is \$25,000.
   a. If a sales tax on food caused the price of food to increase to \$2.50, what would happen to her consumption of food? (*Hint*: Because a large price change is involved, you should assume that the price elasticity measures an arc elasticity, rather than a point elasticity.)
   b. Suppose that Felicia gets a tax rebate of \$2500 to ease the effect of the sales tax. What would her consumption of food be now?
   c. Is she better or worse off when given a rebate equal to the sales tax payments? Draw a graph and explain.

12. You run a small business and would like to predict what will happen to the quantity demanded for your product if you raise your price. While you do not know the exact demand curve for your product, you do know that in the first year you charged \$45 and sold 1200 units and that in the second year you charged \$30 and sold 1800 units.
   a. If you plan to raise your price by 10 percent, what would be a reasonable estimate of what will happen to quantity demanded in percentage terms?
   b. If you raise your price by 10 percent, will revenue increase or decrease?

13. Suppose you are in charge of a toll bridge that costs essentially nothing to operate. The demand for bridge crossings Q is given by $P = 15 - (1/2)Q$.
   a. Draw the demand curve for bridge crossings.
   b. How many people would cross the bridge if there were no toll?

c. What is the loss of consumer surplus associated with a bridge toll of $5?

d. The toll-bridge operator is considering an increase in the toll to $7. At this higher price, how many people would cross the bridge? Would the toll-bridge revenue increase or decrease? What does your answer tell you about the elasticity of demand?

e. Find the lost consumer surplus associated with the increase in the price of the toll from $5 to $7.

14. Vera has decided to upgrade the operating system on her new PC. She hears that the new Linux operating system is technologically superior to Windows and substantially lower in price. However, when she asks her friends, it turns out they all use PCs with Windows. They agree that Linux is more appealing but add that they see relatively few copies of Linux on sale at local stores. Vera chooses Windows. Can you explain her decision?

15. Suppose that you are the consultant to an agricultural cooperative that is deciding whether members should cut their production of cotton in half next year. The cooperative wants your advice as to whether this action will increase members' revenues. Knowing that cotton (C) and watermelons (W) both compete for agricultural land in the South, you estimate the demand for cotton to be $C = 3.5 - 1.0P_C + 0.25P_W + 0.50I$, where P_C is the price of cotton, P_W the price of watermelon, and I income. Should you support or oppose the plan? Is there any additional information that would help you to provide a definitive answer?

Appendix to Chapter 4

DEMAND THEORY—A MATHEMATICAL TREATMENT

This appendix presents a mathematical treatment of the basics of demand theory. Our goal is to provide a short overview of the theory of demand for students who have some familiarity with the use of calculus. To do this, we will explain and then apply the concept of constrained optimization.

Utility Maximization

The theory of consumer behavior is based on the assumption that consumers maximize utility subject to the constraint of a limited budget. We saw in Chapter 3 that for each consumer, we can define a *utility function* that attaches a level of utility to each market basket. We also saw that the *marginal utility* of a good is defined as the change in utility associated with a one-unit increase in the consumption of the good. Using calculus, as we do in this appendix, we measure marginal utility as the utility change that results from a very small increase in consumption.

In §3.1, we explain that a utility function is a formula that assigns a level of utility to each market basket.

Suppose, for example, that Bob's utility function is given by $U(X, Y) = \log X + \log Y$, where, for the sake of generality, X is now used to represent food and Y represents clothing. In that case, the marginal utility associated with the additional consumption of X is given by *the partial derivative of the utility function with respect to good X*. Here, MU_X, representing the marginal utility of good X, is given by

In §3.5, marginal utility is described as the additional satisfaction obtained by consuming an additional amount of a good.

$$\frac{\partial U(X,Y)}{\partial X} = \frac{\partial(\log X + \log Y)}{\partial X} = \frac{1}{X}$$

In the following analysis, we will assume, as in Chapter 3, that while the level of utility is an *increasing* function of the quantities of goods consumed, marginal utility *decreases* with consumption. When there are two goods, X and Y, the consumer's optimization problem may thus be written as

$$\text{Maximize } U(X, Y) \qquad \textbf{(A4.1)}$$

subject to the constraint that all income is spent on the two goods:

$$P_X X + P_Y Y = I \qquad \textbf{(A4.2)}$$

Here, $U(\,)$ is the utility function, X and Y the quantities of the two goods purchased, P_X and P_Y the prices of the goods, and I income.[1]

To determine the individual consumer's demand for the two goods, we choose those values of X and Y that maximize (A4.1) subject to (A4.2). When we know the particular form of the utility function, we can solve to find the consumer's demand for X and Y directly. However, even if we write the utility function in its general form $U(X, Y)$, the technique of *constrained optimization* can be used to describe the conditions that must hold if the consumer is maximizing utility.

[1]To simplify the mathematics, we assume that the utility function is continuous (with continuous derivatives) and that goods are infinitely divisible. The logarithmic function log (.) measures the natural logarithm of a number.

The Method of Lagrange Multipliers

• method of Lagrange multipliers Technique to maximize or minimize a function subject to one or more constraints.

• Lagrangian Function to be maximized or minimized, plus a variable (the *Lagrange multiplier*) multiplied by the constraint.

The **method of Lagrange multipliers** is a technique that can be used to maximize or minimize a function subject to one or more constraints. Because we will use this technique to analyze production and cost issues later in the book, we will provide a step-by-step application of the method to the problem of finding the consumer's optimization given by equations (A4.1) and (A4.2).

1. **Stating the Problem** First, we write the Lagrangian for the problem. The **Lagrangian** is the function to be maximized or minimized (here, utility is being maximized), plus a variable which we call λ times the constraint (here, the consumer's budget constraint). We will interpret the meaning of λ in a moment. The Lagrangian is then

$$\Phi = U(X, Y) - \lambda(P_X X + P_Y Y - I) \qquad \textbf{(A4.3)}$$

Note that we have written the budget constraint as

$$P_X X + P_Y Y - I = 0$$

i.e., as a sum of terms that is equal to zero. We then insert this sum into the Lagrangian.

2. **Differentiating the Lagrangian** If we choose values of X and Y that satisfy the budget constraint, then the second term in equation (A4.3) will be zero. Maximizing will therefore be equivalent to maximizing $U(X, Y)$. By differentiating Φ with respect to X, Y, and λ and then equating the derivatives to zero, we can obtain the necessary conditions for a maximum.[2] The resulting equations are

$$\begin{aligned} \frac{\partial \Phi}{\partial X} &= \text{MU}_X(X, Y) - \lambda P_X = 0 \\ \frac{\partial \Phi}{\partial Y} &= \text{MU}_Y(X, Y) - \lambda P_Y = 0 \\ \frac{\partial \Phi}{\partial \lambda} &= I - P_X X - P_Y Y = 0 \end{aligned} \qquad \textbf{(A4.4)}$$

Here as before, MU is short for *marginal utility*: In other words, $\text{MU}_X(X, Y) = \partial U(X, Y)/\partial X$, the change in utility from a very small increase in the consumption of good X.

3. **Solving the Resulting Equations** The three equations in (A4.4) can be rewritten as

$$\begin{aligned} \text{MU}_X &= \lambda P_X \\ \text{MU}_Y &= \lambda P_Y \\ P_X X + P_Y Y &= I \end{aligned}$$

[2] These conditions are necessary for an "interior" solution in which the consumer consumes positive amounts of both goods. The solution, however, could be a "corner" solution in which all of one good and none of the other is consumed.

Now we can solve these three equations for the three unknowns. The resulting values of X and Y are the solution to the consumer's optimization problem: They are the utility-maximizing quantities.

The Equal Marginal Principle

The third equation above is the consumer's budget constraint with which we started. The first two equations tell us that each good will be consumed up to the point at which the marginal utility from consumption is a multiple (λ) of the price of the good. To see the implication of this, we combine the first two conditions to obtain the *equal marginal principle*:

$$\lambda = \frac{MU_X(X, Y)}{P_X} = \frac{MU_Y(X, Y)}{P_Y} \qquad \textbf{(A4.5)}$$

In other words, the marginal utility of each good divided by its price is the same. To optimize, *the consumer must get the same utility from the last dollar spent by consuming either X or Y*. If this were not the case, consuming more of one good and less of the other would increase utility.

To characterize the individual's optimum in more detail, we can rewrite the information in (A4.5) to obtain

$$\frac{MU_X(X, Y)}{MU_Y(X, Y)} = \frac{P_X}{P_Y} \qquad \textbf{(A4.6)}$$

In other words, *the ratio of the marginal utilities is equal to the ratio of the prices.*

Marginal Rate of Substitution

We can use equation (A4.6) to see the link between utility functions and indifference curves that was spelled out in Chapter 3. An indifference curve represents all market baskets that give the consumer the same level of utility. If U^* is a fixed utility level, the indifference curve that corresponds to that utility level is given by

In §3.5, we show that the marginal rate of substitution is equal to the ratio of the marginal utilities of the two goods being consumed.

$$U(X, Y) = U^*$$

As the market baskets are changed by adding small amounts of X and subtracting small amounts of Y, the total change in utility must equal zero. Therefore,

$$MU_X(X, Y)dX + MU_Y(X, Y)dY = dU^* = 0 \qquad \textbf{(A4.7)}$$

Rearranging,

$$-dY/dX = MU_X(X, Y)/MU_Y(X, Y) = MRS_{XY} \qquad \textbf{(A4.8)}$$

where MRS_{XY} represents the individual's marginal rate of substitution of X for Y. Because the left-hand side of (A4.8) represents the negative of the slope of the indifference curve, it follows that at the point of tangency, the individual's marginal rate of substitution (which trades off goods while keeping utility constant) is equal to the individual's ratio of marginal utilities, which in turn is equal to the ratio of the prices of the two goods, from (A4.6).[3]

When the individual indifference curves are convex, the tangency of the indifference curve to the budget line solves the consumer's optimization problem. This principle was illustrated by Figure 3.13 (page 87) in Chapter 3.

Marginal Utility of Income

Whatever the form of the utility function, the Lagrange multiplier λ represents the extra utility generated when the budget constraint is relaxed—in this case by adding one dollar to the budget. To show how the principle works, we differentiate the utility function $U(X, Y)$ totally with respect to I:

$$dU/dI = \mathrm{MU}_X(X, Y)(dX/dI) + \mathrm{MU}_Y(X, Y)(dY/dI) \qquad \textbf{(A4.9)}$$

Because any increment in income must be divided between the two goods, it follows that

$$dI = P_X dX + P_Y dY \qquad \textbf{(A4.10)}$$

Substituting from (A4.5) into (A4.9), we get

$$dU/dI = \lambda P_X(dX/dI) + \lambda P_Y(dY/dI) = \lambda(P_X dX + P_Y dY)/dI \qquad \textbf{(A4.11)}$$

and substituting (A4.10) into (A4.11), we get

$$dU/dI = \lambda(P_X dX + P_Y dY)/(P_X dX + P_Y dY) = \lambda \qquad \textbf{(A4.12)}$$

Thus the *Lagrange multiplier* is the extra utility that results from an extra dollar of income.

Going back to our original analysis of the conditions for utility maximization, we see from equation (A4.5) that maximization requires the utility obtained from the consumption of every good, per dollar spent on that good, to be equal to the marginal utility of an additional dollar of income. If this were not the case, utility could be increased by spending more on the good with the higher ratio of marginal utility to price and less on the other good.

An Example

In general, the three equations in (A4.4) can be solved to determine the three unknowns X, Y, and λ as a function of the two prices and income. Substitution for λ then allows us to solve for the demand for each of the two goods in terms of income and the prices of the two commodities. This principle can be most easily seen in terms of an example.

• **Cobb-Douglas utility function** Utility function $U(X,Y) = X^a Y^{1-a}$, where X and Y are two goods and a is a constant.

A frequently used utility function is the **Cobb-Douglas utility function**, which can be represented in two forms:

$$U(X, Y) = a \log(X) + (1 - a) \log(Y)$$

[3]We implicitly assume that the "second-order conditions" for a utility maximum hold. The consumer, therefore, is maximizing rather than minimizing utility. The convexity condition is sufficient for the second-order conditions to be satisfied. In mathematical terms, the condition is that $d(\mathrm{MRS})/dX < 0$ or that $dY^2/dX^2 > 0$ where $-dY/dX$ is the slope of the indifference curve. Remember: diminishing marginal utility is not sufficient to ensure that indifference curves are convex.

and

$$U(X, Y) = X^a Y^{1-a}$$

For the purposes of demand theory, these two forms are equivalent because they both yield the identical demand functions for goods X and Y. We will derive the demand functions for the first form and leave the second as an exercise for the student.

To find the demand functions for X and Y, given the usual budget constraint, we first write the Lagrangian:

$$\Phi = a\log(X) + (1-a)\log(Y) - \lambda(P_X X + P_Y Y - I)$$

Now differentiating with respect to X, Y, and λ and setting the derivatives equal to zero, we obtain

$$\partial\Phi/\partial X = a/X - \lambda P_X = 0$$
$$\partial\Phi/\partial Y = (1-a)/Y - \lambda P_Y = 0$$
$$\partial\Phi/\partial\lambda = P_X X + P_Y Y - I = 0$$

The first two conditions imply that

$$P_X X = a/\lambda \qquad \textbf{(A4.13)}$$

$$P_Y Y = (1-a)/\lambda \qquad \textbf{(A4.14)}$$

Combining these expressions with the last condition (the budget constraint) gives us

$$a/\lambda + (1-a)/\lambda - I = 0$$

or $\lambda = 1/I$. Now we can substitute this expression for λ back into (A4.13) and (A4.14) to obtain the demand functions:

$$X = (a/P_X)I$$
$$Y = [(1-a)/P_Y]I$$

In this example, the demand for each good depends only on the price of that good and on income, not on the price of the other good. Thus, the cross-price elasticities of demand are 0.

In §2.4, we explain that the cross-price elasticity of demand refers to the percentage change in the quantity demanded of one good that results from a 1-percent increase in the price of another good.

We can also use this example to review the meaning of Lagrange multipliers. To do so, let's substitute specific values for each of the parameters in the problem. Let $a = 1/2$, $P_X = \$1$, $P_Y = \$2$, and $I = \$100$. In this case, the choices that maximize utility are $X = 50$ and $Y = 25$. Also note that $\lambda = 1/100$. The Lagrange multiplier tells us that if an additional dollar of income were available to the consumer, the level of utility achieved would increase by 1/100. This conclusion is relatively easy to check. With an income of \$101, the maximizing choices of the two goods are $X = 50.5$ and $Y = 25.25$. A bit of arithmetic tells us that the original level of utility is 3.565 and the new level of utility 3.575. As we can see, the additional dollar of income has indeed increased utility by .01, or 1/100.

Duality in Consumer Theory

There are two different ways of looking at the consumer's optimization decision. The optimum choice of X and Y can be analyzed not only as the problem of choosing the highest indifference curve—the maximum value of $U(\,)$—that touches the budget line, but also as the problem of choosing the lowest budget line—the minimum budget expenditure—that touches a given indifference curve. We use the term **duality** to refer to these two perspectives. To see how this principle works, consider the following dual consumer optimization problem: the problem of minimizing the cost of achieving a particular level of utility:

• **duality** Alternative way of looking at the consumer's utility maximization decision: Rather than choosing the highest indifference curve, given a budget constraint, the consumer chooses the lowest budget line that touches a given indifference curve.

$$\text{Minimize } P_X X + P_Y Y$$

subject to the constraint that

$$U(X, Y) = U^*$$

The corresponding Lagrangian is given by

$$\Phi = P_X X + P_Y Y - \mu(U(X, Y) - U^*) \qquad \textbf{(A4.15)}$$

where μ is the Lagrange multiplier. Differentiating Φ with respect to X, Y, and μ and setting the derivatives equal to zero, we find the following necessary conditions for expenditure minimization:

$$P_X - \mu \text{MU}_X(X, Y) = 0$$
$$P_Y - \mu \text{MU}_Y(X, Y) = 0$$

and

$$U(X, Y) = U^*$$

By solving the first two equations, and recalling (A4.5) we see that

$$\mu = [P_X/\text{MU}_X(X, Y)] = [P_Y/\text{MU}_Y(X, Y)] = 1/\lambda$$

Because it is also true that

$$\text{MU}_X(X, Y)/\text{MU}_Y(X, Y) = \text{MRS}_{XY} = P_X/P_Y$$

the cost-minimizing choice of X and Y must occur at the point of tangency of the budget line and the indifference curve that generates utility U^*. Because this is the same point that maximized utility in our original problem, the dual expenditure-minimization problem yields the same demand functions that are obtained from the direct utility-maximization problem.

To see how the dual approach works, let's reconsider our Cobb-Douglas example. The algebra is somewhat easier to follow if we use the exponential form of the Cobb-Douglas utility function, $U(X, Y) = X^a Y^{1-a}$. In this case, the Lagrangian is given by

$$\Phi = P_X X + P_Y Y - \mu[X^a Y^{1-a} - U^*] \qquad \textbf{(A4.16)}$$

Differentiating with respect to X, Y, and μ and equating to zero, we obtain

$$P_X = \mu a U^*/X$$
$$P_Y = \mu(1-a)U^*/Y$$

Multiplying the first equation by X and the second by Y and adding, we get

$$P_X X + P_Y Y = \mu U^*$$

First, we let I be the cost-minimizing expenditure (if the individual did not spend all of his income to get utility level U^*, U^* would not have maximized utility in the original problem). Then it follows that $\mu = I/U^*$. Substituting in the equations above, we obtain

$$X = aI/P_X \quad \text{and} \quad Y = (1-a)I/P_Y$$

These are the same demand functions that we obtained before.

Income and Substitution Effects

The demand function tells us how any individual's utility-maximizing choices respond to changes in both income and the prices of goods. It is important, however, to distinguish that portion of any price change that involves *movement along an indifference curve* from that portion which involves *movement to a different indifference curve* (and therefore a change in purchasing power). To make this distinction, we consider what happens to the demand for good X when the price of X changes. As we explained in Section 4.2, the change in demand can be divided into a *substitution effect* (the change in quantity demanded when the level of utility is fixed) and an *income effect* (the change in the quantity demanded with the level of utility changing but the relative price of good X unchanged). We denote the change in X that results from a unit change in the price of X, holding utility constant, by

In §4.2, the effect of a price change is divided into an income effect and a substitution effect.

$$\partial X/\partial P_{X\,|\,U=U^*}$$

Thus the total change in the quantity demanded of X resulting from a unit change in P_X is

$$dX/dP_X = \partial X/\partial P_{X\,|\,U=U^*} + (\partial X/\partial I)(\partial I/\partial P_X) \qquad \textbf{(A4.17)}$$

The first term on the right side of equation (A4.17) is the substitution effect (because utility is fixed); the second term is the income effect (because income increases).

From the consumer's budget constraint, $I = P_X X + P_Y Y$, we know by differentiation that

$$\partial I/\partial P_X = X \qquad \textbf{(A4.18)}$$

Suppose for the moment that the consumer owned goods X and Y. In that case, equation (A4.18) would tell us that when the price of good X increases by \$1, the amount of income that the consumer can obtain by selling the good increases by \$$X$. In our theory of consumer behavior, however, the consumer does not own the good. As a result, equation (A4.18) tells us how much additional income the consumer would need in order to be as well off after the price change as he or she was before. For this reason, it is customary to write the income effect as negative (reflecting a loss of purchasing power) rather than as a positive. Equation (A4.17) then appears as follows:

$$dX/dP_X = \partial X/\partial P_{X\,|\,U=U^*} - X(\partial X/\partial I) \qquad \textbf{(A4.19)}$$

• **Slutsky equation** Formula for decomposing the effects of a price change into substitution and income effects.

In this new form, called the **Slutsky equation**, the first term represents the *substitution effect*: the change in demand for good X obtained by keeping utility fixed. The second term is the *income effect*: the change in purchasing power resulting from the price change times the change in demand resulting from a change in purchasing power.

An alternative way to decompose a price change into substitution and income effects, which is usually attributed to John Hicks, does not involve indifference curves. In Figure A4.1, the consumer initially chooses market basket A on budget line RS. Suppose that after the price of food falls (and the budget line moves to RT), we take away enough income so that the individual is no better off (and no worse off) than he was before. To do so, we draw a budget line parallel to RT. If the budget line passed through A, the consumer would be at

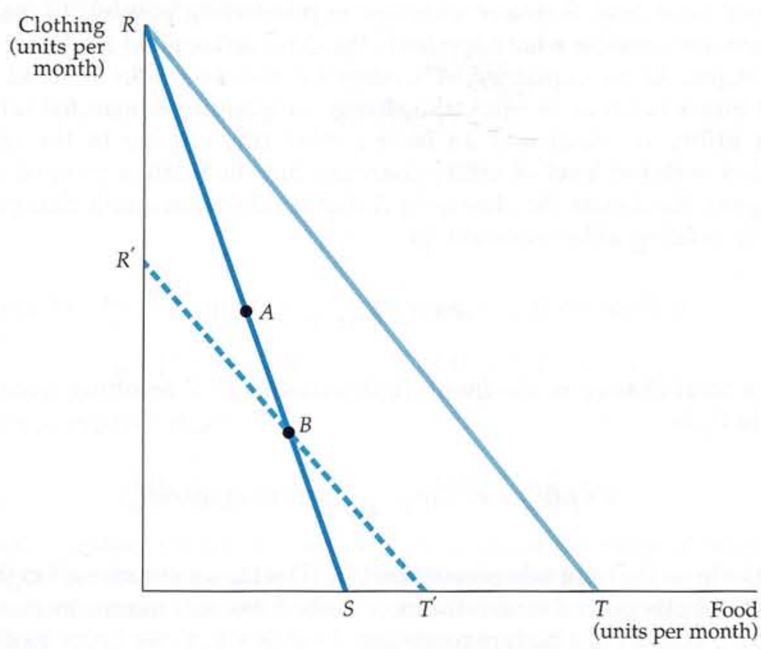

FIGURE A4.1 Hicksian Substitution Effect

The individual initially consumes market basket A. A decrease in the price of food shifts the budget line from RS to RT. If a sufficient amount of income is taken away to make the individual no better off than he or she was at A, two conditions must be met: The new market basket chosen must lie on line segment BT' of budget line $R'T'$ (which intersects RS to the right of A), and the quantity of food consumed must be greater than at A.

least as satisfied as he was before the price change: He still has the option to purchase market basket A if he wishes. According to the **Hicksian substitution effect**, therefore, the budget line that leaves him equally well off must be a line such as $R'T'$, which is parallel to RT and which intersects RS at a point B below and to the right of point A.

• **Hicksian substitution effect** Alternative to the Slutsky equation for decomposing price changes without recourse to indifference curves.

Revealed preference tells us that the newly chosen market basket must lie on line segment BT'. Why? Because all market baskets on line segment $R'B$ could have been chosen but were not when the original budget line was RS. (Recall that the consumer preferred basket A to any other feasible market basket.) Now note that all points on line segment BT' involve more food consumption than does basket A. It follows that the quantity of food demanded increases whenever there is a decrease in the price of food with utility held constant. This negative substitution effect holds for all price changes and does not rely on the assumption of convexity of indifference curves that we made in Section 3.1 (page 69).

In §3.4, we explain how information about consumer preferences is revealed through the consumption choices that consumers make.

In §3.1, we explain that an indifference curve is convex if the marginal rate of substitution diminishes as we move down along the curve.

EXERCISES

1. Which of the following utility functions are consistent with convex indifference curves and which are not?
   a. $U(X, Y) = 2X + 5Y$
   b. $U(X, Y) = (XY)^{.5}$
   c. $U(X, Y) = \text{Min}(X, Y)$, where Min is the minimum of the two values of X and Y.
2. Show that the two utility functions given below generate identical demand functions for goods X and Y:
   a. $U(X, Y) = \log(X) + \log(Y)$
   b. $U(X, Y) = (XY)^{.5}$
3. Assume that a utility function is given by $\text{Min}(X, Y)$, as in Exercise 1(c). What is the Slutsky equation that decomposes the change in the demand for X in response to a change in its price? What is the income effect? What is the substitution effect?
4. Sharon has the following utility function:

$$U(X, Y) = \sqrt{X} + \sqrt{Y}$$

   where X is her consumption of candy bars, with price $P_X = \$1$, and Y is her consumption of espressos, with $P_Y = \$3$.
   a. Derive Sharon's demand for candy bars and espresso.
   b. Assume that her income $I = \$100$. How many candy bars and how many espressos will Sharon consume?
   c. What is the marginal utility of income?
5. Maurice has the following utility function:

$$U(X, Y) = 20X + 80Y - X^2 - 2Y^2$$

   where X is his consumption of CDs with a price of \$1 and Y is his consumption of movie videos, with a rental price of \$2. He plans to spend \$41 on both forms of entertainment. Determine the number of CDs and video rentals that will maximize Maurice's utility.