

# 3

## Supply and Demand: Where do Prices come from?

3.1	Overview	58
3.2	The Middletown housing market, a parable	58
3.3	The Econoland corn market	64
3.3.1	Crop failure	67
3.3.2	Consumer surplus	68
3.3.3	Price controls and rationing	71
3.4	Demand and supply curve shifters	71
3.4.1	Some demand curve shifters	71
3.4.2	Some supply curve shifters	72
3.4.3	Recapitulation	73
3.4.4	Functions of several variables and partial derivatives	73
3.5	Elasticity	75
3.5.1	Arc-elasticity	77
3.5.2	Point elasticity	78
3.5.3	Price versus income elasticity	82
3.5.4	Some elasticity estimates	83
3.6	Some applications	85
3.6.1	Paradoxes resolved	85
3.6.2	The minimum wage	85
3.6.3	Farm price supports	87
3.7	Foreign exchange rates	90
3.7.1	Demand and supply	91
3.7.2	Fixed versus floating exchange rates	94
3.7.3	The United States, A debtor nation	96
3.8	Taxes	97
3.8.1	Tax incidence	100
3.8.2	Maximizing tax revenue — The Laffer curve	102
3.8.3	Consumer surplus, producer surplus, and the excess burden	105
3.8.4	Tariffs, quotas and the gains from trade	109
3.9	Markets versus the ballot box	111
	Summary	115
	Key Concepts	116
	Exercises	116

### 3.1 Overview

Where do prices come from? Why do they fluctuate? While we found in the preceding chapter that prices can guide production decisions, we did not learn what determines prices. The task of this chapter is to find out how markets work to determine price and output.

Here are some of the issues explored in this chapter: How do crop failures, taxes, subsidies, and government price controls influence prices? Why are shortages the natural but unintended consequence when governments impose price controls in an attempt to ease the pain of rising prices? Why do price floors generate surpluses? Does the minimum wage cause unemployment?

We shall learn how to measure the responsiveness of quantity consumed to changes in income and prices. We shall also learn how to measure the excess burden that taxes impose on producers and consumers.

*Caveat:* The discussion in this chapter will be limited to the case of *competition*. That is to say, we shall be assuming that there are a large number of buyers and sellers. Later, Chapter 6 will analyze a variety of alternative market forms, including monopoly.

### 3.2 The Middletown housing market, a parable

To start with the simplest possible example, consider the market for rental housing in Middletown. To keep things simple, suppose that there are 1,000 identical housing units. The landlords would obviously like to collect as much rent as possible. Tenants prefer to pay low rent. How will these opposing interests be reconciled?

What the rent will turn out to be depends in part on how much consumers are willing to spend. If the rent is low enough, many will want their own place. At a higher rent, people will double up (students will go home to live with their parents after they graduate from college). And if the rent is extremely high, everyone will sleep in the park. Suppose that a market survey reveals the following facts about the demand for housing in Middletown:

- No one is willing to spend more than \$900 per month to rent an apartment.
- Five hundred people are willing to spend \$600 or more to rent an apartment.

- If the rent were zero, 1,500 families would want to occupy apartments

The evidence provided by the survey is plotted in Figure 3.1. The rent (price) is on the ordinate and the number of apartments that are rented is plotted on the abscissa.<sup>1</sup> The three observations provided by the survey are plotted at  $\langle 0, \$900 \rangle$ ,  $\langle 500, \$600 \rangle$ , and  $\langle 1500, 0 \rangle$ . The straight line connecting the hypothetical data points provides a reasonable guess as to how the number of apartments people want to rent — the demand for housing — is related to the price, everything else constant. This is the demand curve.

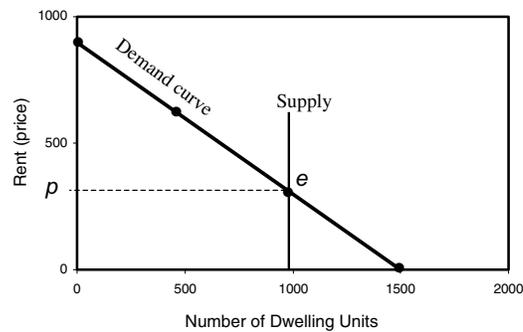


Fig. 3.1. The market for rental housing  
The demand curve shows the quantity that people want to buy as a function of price. The equilibrium point, where demand equals supply, is marked with an  $e$ . This intersection point determines both price and quantity.

This relationship between quantity and price is captured by the following *demand function*,

$$q = 1500 - \frac{5}{3}p, \quad (1)$$

for  $p$  in the range  $0 \leq p \leq 900$ . Note that at a price of  $p = \$900$  no one will rent an apartment — this point on the graph, the  $y$ -intercept, is known as the choke point.

<sup>1</sup>Economists customarily plot price on the ordinate and quantity on the abscissa. It was not always so: pioneering French mathematical economist Antoine A. Cournot [1783–1850] plotted quantity on the ordinate and price on the abscissa in his *Principes Mathématiques de la Théorie des Richesses*. But rightly or wrongly, the reverse convention is now firmly established.

The fixed supply of only 1,000 housing units is indicated by the vertical line on our graph. What price will prevail in this market?

- Could the rent be \$450 per month? Equation (1) tells us that at this rent consumers would only want to rent 750 of the identical housing units. Landlords would be stuck with 250 empty apartments. Rather than let an empty apartment earn zero rent, any landlord who did not succeed in renting an apartment for \$450 will have every incentive to cut the price, say to \$440 per month. This lower price will either attract a new tenant or steal a renter from another landlord who was getting \$450.
- Even if all landlords succumb to the market pressure and lower the price to \$440, there will still be excess supply. At that price only about 767 apartments will be rented — there will be 233 vacant apartments earning zero rent. There will be pressure for still more price concessions.

The downward spiral will continue, but not indefinitely.

- At a price of \$300 the resulting demand for 1,000 housing units will precisely equal the supply.

The tenants may hope that the price will be pushed below \$300. To see why this cannot happen, let us suppose the contrary. If, for example, the prevailing price were \$150, the graph tells us that there would be demand for 1,250 apartments; but only 1,000 are available. Some of these 1,250 potential renters, finding that they cannot rent for \$150, will offer to pay a higher rent. Landlords, tempted by the higher offer, will evict their present tenants, unless they agree to match the outsider's offer. This holds for any price below that which equates demand with supply, because such a price generates excess demand. Thus the only price that can prevail in this market is \$300. At this rent, the demand for housing precisely equals the supply. We say that a *market equilibrium* has been established when the quantity demanded equals supply because at this unique price there is no inherent tendency for the price to change.

### *Urban Renewal*

The equilibrium price may fluctuate as a result of changes external to the market. Suppose, for example, that the City Planners decide that the time is ripe for urban renewal. Suppose that the government purchases 250 apartments from their owners and tears them down in order to convert the vacated land into a public park. How will this affect the housing market? Figure 3.2 shows what happens. The supply curve is shifted over to the left

to  $1,000 - 250 = 750$  dwelling units. As a result, there would be a shortage of housing if the price of \$300 were to prevail. The market forces respond, rents are bid up, and eventually equilibrium is restored to the housing market at point  $e'$  on the graph when demand once more equals supply, and this yields a higher rent of \$450.

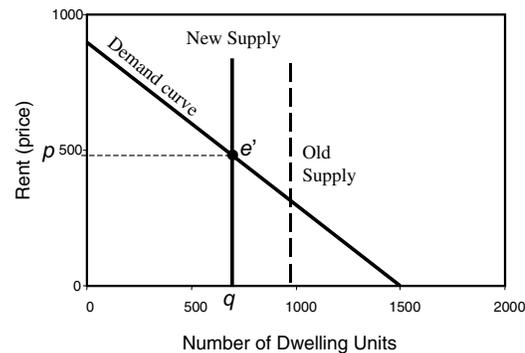


Fig. 3.2. Reduced supply

When supply is reduced to 750 dwelling units, the equilibrium point slides up the demand curve. Price rises to the point where demand is reduced to 750 dwelling units at new equilibrium point  $e'$ .

Who gains and who loses from the reduction in housing? The landlords who sold out were compensated when the town paid for the apartments. The landlords who retained their apartments are earning more rent. But the poor tenants are paying \$450 rent on 750 apartments, for a total of \$337,500. Before they were paying \$300 rent for 1000 apartments, or \$300,000! They are paying more money for less housing!

Studying the revenue rectangle demarcated by points  $p$ ,  $e'$ ,  $q$ ,  $0$  on Figure 3.2 will show why this happens. The area of this rectangle is height times width, or rent of \$450 times quantity of 750; thus the area of this revenue rectangle represents the total rent that landlords collect after the reduction in supply. It is obviously larger than the area of the revenue rectangle generated by the old equilibrium point  $e$  with coordinates (1000, \$300) on Figure 3.1. Note that a further reduction in the number of apartments, say to 500, would cause rent to climb to \$600 but would reduce the total rent collected by landlords to \$300,000.

*Rent Control*

Landlords are never popular. Suppose that the tenants persuade the town planners that the landlords are profiteering from urban renewal by charging exorbitant rents. Suppose that rent controls are enacted rolling rents back to the old level of \$300. Now there are 1,000 people trying to rent 750 apartments. There is a housing shortage. Those who are lucky (or have connections or pay bribes) will get an apartment; others must do without.<sup>2</sup>

While this parable helps to provide an intuitive introduction to how markets work, it is obviously a gross simplification of housing markets in practice. In order to focus on the essential features of the market it was appropriate to assume that all apartments are the same.<sup>3</sup> Our analysis did not allow for the fact that supply of housing will eventually respond to changes in price. If rents rise, landlords may find that it has become profitable to construct new housing. If rents are kept too low, either by rent control or by adverse market conditions, landlords will lose money. They would like to sell out, but will find that no one else will want to take over their money losing property. Stuck with their losses, the landlords are all too likely to let their apartments decay. They fall behind in paying their property taxes to the city. If things get too bad the landlord will miss payments on the mortgage, and the bank will threaten to foreclose on the delinquent landlord and take possession of the building. Eventually the building may be abandoned. Thus housing deterioration may at times be the unintended consequence of rent control.

*Key Concepts*

While the story of the rental market is a simple one, it does serve to illustrate certain basic concepts that are of fundamental importance in understanding how markets work:

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<sup>2</sup>Rent regulation has at times been a major issue in New York City politics. Tenants who lived in an apartment constructed before 1947 were protected by the regulation if they or a close relative had occupied the apartment since 1971. One of the beneficiaries was film star Mia Farrow, who paid only a fraction of the market rent for a ten room apartment on Central Park West. She had inherited the lease on the rent controlled apartment from her mother.

<sup>3</sup>The model of Monopolistic Competition presented in Chapter 6 will consider markets characterized by product differentiation, such as a rental market in which apartments have their own individualizing features.

*Supply and Demand: Where do prices come from?* 63

- The *demand function* shows how much customers will buy as a function of price. The plot of this relationship on a graph is the *demand curve*.
- The *equilibrium price* equates demand with supply.
- If the price is above the equilibrium price, the quantity supplied will exceed demand; i.e., there will be *excess supply*, and landlords will complain that there is a housing surplus.
- If the price is below the equilibrium price, the quantity supplied will fall short of demand; i.e., there will be *excess demand*; and tenants will complain that there is a housing shortage.
- *Price ceilings* (e.g., rent control) will generate a shortage, supply falling short of demand.

*The Law of Demand:* Our conclusion that a reduction in supply generated by urban renewal would lead to an increase in rents relied on the assumption that the demand curve was downward sloping; otherwise, the reduction in supply might have led to a fall in rents! Economists generally believe that this is almost always the case. Indeed, the proposition that demand curves are downward sloping, that demand is a negative function of price, is regarded as so fundamental that it is often referred to as the *Law of Demand*. While this proposition is accepted as a general rule, there may be exceptions:

1. Price is sometimes regarded as an indicator of quality. If the price of something is so low as to sound “almost too good to be true,” it probably isn’t. Demand will drop off if an extremely low price signals, rightly or wrongly, that the item may be shoddy, defective or stolen.
2. A price increase today may be a harbinger of more in the future. If prices are going to rise even higher, it is best to purchase more today.
3. A high price may generate snob appeal. Who, other than an accountant or an economist, would want to be seen wearing a \$10 watch!

All of these examples are exceptions to the rule that demand curves almost always have a negative slope.<sup>4</sup>

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<sup>4</sup>In addition to these three reasons we will find in Chapter 4 that under certain circumstances a rational consumer might in rare circumstances respond to rising prices by increasing consumption.

### 3.3 The Econoland corn market

A second hypothetical example will provide additional insight into how markets work. The Econoland corn market is composed of 100 sellers (farmers) and 200 buyers (consumers). All 200 consumers are identical. The quantity of corn (number of bushels) that each consumer will buy, given the price of other commodities, is specified by the following demand schedule:

*Demand:*

price/bushel	\$18	\$16	\$14	\$12	\$10	\$8	\$6	\$4	\$2	\$0
quantity demanded	0	1	2	3	4	5	6	7	8	9

The behavior of the typical consumer (let us say the  $i$ th consumer) is described by the demand function

$$q_i(p) = 9 - \frac{p}{2}, \quad 0 \leq p \leq \$18. \quad (2)$$

Suppose also that all 100 producers are identical. The quantity that the representative producer is willing to market, given the price of seed and other inputs and the price of alternative uses of his corn (e.g., hog production), is given by the following supply schedule:

*Supply:*

price/bushel	\$0	\$2	\$4	\$6	\$8	\$10	\$12	\$14	\$16	\$18
quantity supplied	0	0	6	12	18	24	30	36	42	48

The typical producer (let us say the  $j$ th producer) has supply function

$$s_j(p) = 3p - 6, \quad p \geq 2. \quad (3)$$

In order to determine the price that will prevail in this market it is necessary to construct *market* demand and supply schedules. To see how, observe that if the price were \$8, each of the 200 consumers would want to purchase 5 units, so total demand for the entire market would be 1,000; thus the point (1000, \$8) is on the market demand curve. Also, at the price of \$8 each of the 100 suppliers would produce 18 bushels of corn, so the point (1800, \$8) is on the market supply curve. Successive rows of the following schedule report market demand, market supply and excess demand, given that there are 200 consumers and 100 farmers:

*Supply and Demand: Where do prices come from?* 65

*The market:*

Price	0	\$2	\$4	\$6	\$8	\$10	\$12	\$14	\$16	\$18
Market Demand	1800	1600	1400	1200	1000	800	600	400	200	0
Market Supply	0	0	600	1200	1800	2400	3000	3600	4200	4800
Excess Demand	1800	1600	800	0	-800	-1600	-2400	-3200	-4000	-4800

It is clear from the schedule that the equilibrium price is \$6.00. At any other price, demand does not equal supply; i.e., excess demand is not zero. Observe also that excess supply (quantity supplied exceeding quantity demanded) is the same thing as negative excess demand (quantity demanded exceeding quantity supplied) and vice versa.

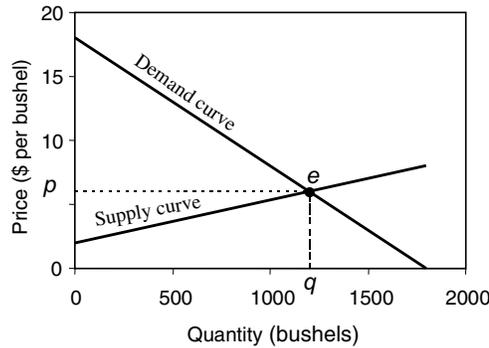


Fig. 3.3. The corn market  
The equilibrium price  $p$  and quantity  $q$  are determined by equilibrium point  $e$  where the demand and supply curve intersect.

The same story is illustrated graphically in Figure 3.3. Point  $e$ , where the market demand and supply curves intersect, reveals the equilibrium price and quantity. This is the only price at which excess demand is zero. A higher price could not prevail because it would elicit the production of more corn than consumers would be willing to buy — excess supply would tend to push the price down. A lower price could not prevail because it would encourage consumers to try to buy more than producers would be willing to bring to market — excess demand would put upward pressure on prices.

It is easy to solve for the market solution algebraically rather than graphically. Since there are 200 consumers, each with demand function

66 *Economics with Calculus*

$q_i(p) = 9 - p/2$ , the market demand function must be

$$q(p) = 200q_i(p) = 1800 - 100p, \quad 0 \leq p \leq \$18. \quad (4)$$

*Notation convention:*  $q_i$  refers to the consumption of the typical ( $i$ th) consumer;  $q$  without the subscript refers to demand for the entire market.

Similarly, since supply is  $s_i(p) = 3p - 6$ ,  $p \geq \$2$ , for each of 100 suppliers, the market supply function must be

$$s(p) = 100s_i(p) = 300p - 600, \quad p \geq \$2. \quad (5)$$

In equilibrium,  $s(p) = q(p)$  or  $300p - 600 = 1800 - 100p$ . Therefore, the equilibrium price is  $p = \$6$  because  $q(\$6) = s(\$6) = 1,200$  bushels.

This corny example was simplified by assuming that all consumers have the same demand function. More generally, suppose there are  $n$  buyers and  $m$  sellers. Let  $q_i(p)$  denote the amount of corn that the  $i$ th consumer will want to purchase as a function of its price; then *market demand* will be

$$q(p) = q_1(p) + q_2(p) + \cdots + q_n(p). \quad (6)$$

Similarly, if there are  $m$  sellers with supply functions  $s_i(p)$ , *market supply* will be

$$s(p) = s_1(p) + s_2(p) + \cdots + s_m(p). \quad (7)$$

Clearly, at the price for which  $q(p) = s(p)$ , we must have

$$q_1(p) + q_2(p) + \cdots + q_n(p) = s_1(p) + \cdots + s_m(p). \quad (8)$$

While it is usually most convenient to think of quantity sold as a function of price, it is sometimes useful to think of the *inverse demand function*,  $p(q) = q^{-1}(p)$ . For our corn example we had  $q(p) = 1800 - 100p$  and so the inverse demand function is

$$p(q) = q^{-1}(p) = 18 - \frac{q}{100}. \quad (9)$$

### *Summary*

The equilibrium market price has been determined by the free play of market forces. Neither the buyers nor the sellers have been able to dictate the price. They are price takers rather than price setters. They have to take the price offered by the market.

The *market equilibrium* has the following features:

- All buyers are purchasing the quantity they wish to purchase at the prevailing market price.
- All sellers are selling the quantity they wish to sell at the prevailing market price.
- Both buyers and sellers are *price takers*. Price takers must accept the price determined in the market. Later we will study *price setters* — a buyer or seller who is big enough to be able to influence the market price.

If the farmers could organize to keep some of their product off the market, they might be able to push the price up. Attempts by groups of farmers to act as price setters have been made from time to time, but except when supported by government intervention, attempts by a large group of suppliers to fight the market are almost always overwhelmed by the forces of competition.

If the government had intervened, as with price controls, things would obviously have worked out differently. As we shall see in a later chapter, the outcome will be quite different if there are a small number of buyers or a small number of sellers, for then they may be able to work deliberately together to affect the price.

### 3.3.1 *Crop failure*

Prices fluctuate in response to a variety of market forces. As our first example, suppose that in the spring each farmer, in anticipation of a price of \$6, plants 12 bushels of corn. But then as a result of a July blight the crop falls short and each of the 100 farmers will be able to bring only 7.5 bushels to market at harvest time. Since it is much too late in the season to even think about replanting, only 750 bushels of corn will be available in the fall. What happens is illustrated in Figure 3.4. There is a new “short run” supply curve showing that, regardless of price, only 750 bushels of corn will arrive on the market. As a result of this “negative supply shock,” the new market equilibrium price will climb to \$10.50 per bushel, as indicated by point  $e'$  on the graph. Alternatively, substituting the supply of 750 into our inverse demand function, equation (9), yields  $p = \$10.50$ .

It may not be surprising to find that the limited supply of corn has caused the price to go up, but note what has happened to revenue. Before the farmers were selling 1,200 bushels at a price of \$6.00, taking home  $\$6 \times 1200 = \$7,200$  from the market. Thanks to the crop failure, they now

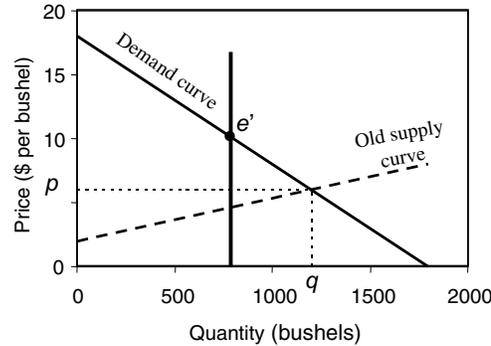


Fig. 3.4. Crop failure

When crops fail and only 750 bushels can be brought to market, the price rises to \$10.50 in order to equate demand with the reduced supply at the new equilibrium point.

bring  $750 \times \$10.50 = \$7,875$  home from the market, \$675 more than before! The seeming paradox that a general crop failure can benefit farmers will be clarified later in this chapter when we discuss the concept of demand elasticity.

### 3.3.2 *Consumer surplus*

How much have the consumers lost as a result of the crop failure? To find out the dollar value of the loss imposed on consumers, we must introduce the concept of consumer surplus. The basic notion of consumer surplus is that the purchasers of a commodity often pay less for that commodity than it is worth to them. An individual buyer's *consumer surplus* is the excess of what that customer would have been willing to pay for a commodity over what it actually costs. For the entire market, we must add up the consumer surplus of each of the individual buyers of the commodity.

The consumer surplus concept is illustrated in Figure 3.5, which shows the hypothetical demand curve for a good book. There are 20 potential purchasers, but some value the book much more than others. The staircase form of the hypothetical demand curve arises because one customer is willing to pay as much as \$100 for the book, the second is willing to pay \$95 but no more, the third \$90 and so on. To determine how much consumer surplus will be realized if the book sells for \$60, note that the book loving customer who would have been willing to pay as much as \$100 only had to pay \$60. The excess of \$40 that this happy consumer would have been

## Supply and Demand: Where do prices come from? 69

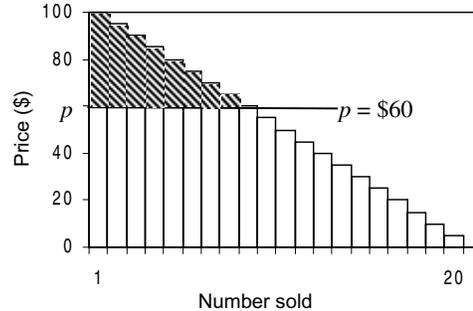


Fig. 3.5. Consumer surplus  
Consumer surplus from purchasing a good book for \$60 is measured by the area between the demand curve and the \$60 price line.

willing to pay over what she actually paid for it is her consumer surplus. The graph also shows that two copies of the book would have been sold if the price were \$95, one to our first consumer and one to a second consumer for whom the book is worth \$95 but not \$100. If this second consumer is able to buy the book for \$60 he will realize consumer surplus of  $\$95 - \$60 = \$45$ . The graph indicates that the first eight buyers of the book all enjoy some consumer surplus, but in decreasing amounts. The buyer of the ninth copy of the book does not enjoy any consumer surplus because this consumer would not be willing to pay a penny more than the \$60 price for the book. The total consumer surplus realized by all the purchasers, represented by the crosshatched area on the graph under the demand curve staircase and above the horizontal price line, is \$180.

When there are a large number of consumers, each buying different quantities, it is natural to draw the demand curve as a downward sloping curve or line rather than as a series of steps, but the logic of consumer surplus remains the same. In Figure 3.6, which reproduces the corn market demand and supply curves from Figure 3.4, the area of the large shaded triangle with vertices  $d$ ,  $e$ ,  $p^e$  represents the consumer surplus when  $p = \$6$ . The area is obviously  $(\$18 - \$6) \times 1200/2 = \$7,200$ .

Quite generally, whether the demand curve is linear or not, we can calculate consumer surplus by integration. Let  $p(q) = q^{-1}(p)$  denote the inverse demand function yielding the market price as a function of quantity sold. Then the consumer surplus at price  $p$  is

$$S_c(p) = \int_0^{q(p)} [p(q) - p] dq. \quad (10)$$

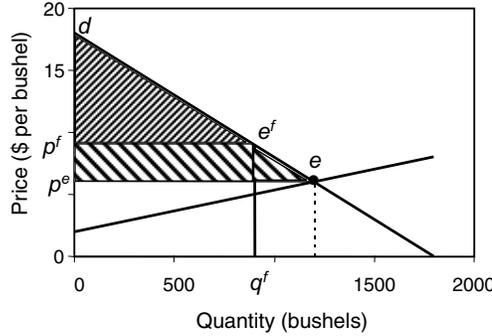


Fig. 3.6. Consumer surplus lost: Crop failure  
 In a good crop year,  $p = \$6$  and consumer surplus is the large shaded triangle with vertexes  $d, e, p^e$ . When crop failure reduces the supply to 900, the price increases to  $\$9.00$  and consumer surplus is only the smaller triangle with vertexes at  $d, e^f, p^f$ . Therefore, the consumer surplus lost as a result of the crop failure is the trapezoid with coordinates  $p^f, e^f, e, p^e$ .

For our hypothetical corn market example we had inverse demand function  $p(q) = 18 - q/100$  and  $p^e = \$6$ ; therefore, the surplus that would be realized if there were no crop failure is

$$S_{c(\$6.00)} = \int_0^{1200} \left(18 - \frac{q}{100} - 6\right) dq = 12q - \frac{q^2}{200} \Big|_0^{1200} = \$7,200, \quad (11)$$

just as the graph suggested.

Now consider the effect of the crop failure that was displayed in Figure 3.4. With output of only 750, the price must rise to  $\$10.50$  in order for demand to equal the reduced supply. As a result of the price rise, the consumer surplus triangle is reduced to  $(18 - 10.50) \times 750/2 = \$2,812.50$ . Or by integration,

$$S_{c(\$10.50)} = \int_0^{750} \left(18 - \frac{q}{100} - 10.5\right) dq = 7.5q - \frac{q^2}{200} \Big|_0^{750} = \$2,812.50. \quad (12)$$

The consumers lose  $\$7,200 - \$2,812.50 = \$4,387.50$  as a result of the crop failure. Since producers gained an offsetting  $\$675$ , the net dollar loss from the crop failure is  $\$4,387.50 - \$675 = \$3,712.50$ .

### 3.3.3 *Price controls and rationing*

Price hikes are never popular. Suppose the government decides to help consumers by imposing a price ceiling of \$6.00 per bushel. This will not lead to any more corn being brought to market. Worse, the controls may discourage farmers from planting much corn next year.

At the price of \$6.00, consumers will want to buy 1,200 bushels but supply will still only be 750. The price cap has generated a shortage of 300 bushels, just as rent controls generate a shortage of housing. Who will get the corn? The grocer may attempt to fairly allocate the corn to regular customers, friends and family. Or the grocer may accept a side payment under the table. Alternatively, the government may ration corn by issuing coupons to each household. In order to buy corn you have to surrender a ration coupon to the seller.

During World War II sugar, gasoline, coffee, meat and a number of other commodities were rationed in the United States. Just counting the coupons was a lot of work. Before too long, sizable portions of the rationed commodities were illegally diverted to the *black market* to be sold at the highest attainable price. Black markets are illegal, but they seldom lack customers. The system of price controls and rationing may explain why there was not more inflation during World War II, but prices soared when the controls were removed shortly after the end of the war. Perhaps the controls only postponed the inflation that was the inevitable consequence of an all out war effort.

## 3.4 Demand and supply curve shifters

A crop failure is only one type of disturbance that can affect the market equilibrium. We shall consider other factors, some of which shift the demand curve while others shift the supply curve.

### 3.4.1 *Some demand curve shifters*

First we shall consider factors that shift the demand curve:

1. When the economy moves into a boom, consumers have more income to spend. They buy more. This will shift the demand curve for most commodities to the right.

So called *inferior goods* are the exception to this rule. If the income increase induces consumers to purchase less corn (perhaps they now buy more meat instead), then corn is an *inferior* good.

2. A farmer's cooperative might stimulate sales by advertising its product.
3. An increase in the price of barley might encourage consumers to *substitute* corn for barley; i.e., consumers may buy more corn instead of barley when the price of barley goes up. This means that the increase in the price of barley has shifted the demand curve for corn upward and to the right, contributing to a rise in the price of corn.
4. An increase in the price of butter might discourage the consumption of corn. If so the demand curve for corn would shift downward and to the left, contributing to a decline in the price of corn.

#### *Substitutes and Complements*

Barley is a substitute for corn while butter is a complement.

- The price of *complementary commodities* (like corn and butter or strawberries and cream) tend to move in opposite directions. Thus a poor strawberry harvest may contribute to a decline in the demand for cream.
- The prices of *substitute commodities* (like corn and barley or raspberries and strawberries) tend to move together.

*Sliding Along the Supply curve:* Demand curve shifters cause the equilibrium point to slide along a stable supply curve.

- If the demand curve shifts up or to the right, the equilibrium point will slide up the supply curve, which causes both quantity and price to increase.
- If the demand curve shifts to the left, perhaps because the economy has moved into a recession, the equilibrium point will slide down the supply curve and both quantity and price will decline.

#### **3.4.2** *Some supply curve shifters*

Some types of disturbances shift the supply curve rather than the demand curve:

- A fall in the price of hogs may encourage farmers to bring more corn to market rather than feed it to their pigs. This will push the market

*Supply and Demand: Where do prices come from?* 73

supply curve of corn to the right, the equilibrium point will slide down the stable demand curve for corn. As a result, the price of corn falls but the quantity sold increases.

- An increase in the price of diesel fuel will make it more expensive for farmers to run their trucks and tractors. At any given price the farmer is likely to bring less to market. Some farmers may go out of business. All this means that the supply curve shifts upwards. The equilibrium point will slide up the demand curve and quantity sold will drop off.

**3.4.3 Recapitulation**

The demand and supply curve apparatus provides a convenient framework for examining the effect of a variety of market disturbances. The trick in putting this apparatus to work is to decide whether the disturbance affects the position of the demand curve, the position of the supply curve, or both.

There is a key difference between demand and supply curve shifters: Demand curve shifters cause price and quantity to move in the same direction (both up or both down) because the equilibrium point slides along the *positively* sloped supply curve. Supply curve shifters cause price and quantity to move in opposite directions (if price goes up, quantity goes down, or vice versa) because the equilibrium point slides along the *negatively* sloped demand curve.

Sometimes the demand and supply curves will shift simultaneously. For example, the increase in the price of barley may not only cause consumers to shift to consuming more corn; it may also induce some farmers to shift time and land from the production of corn into the production of the more expensive barley, pushing the supply curve for corn to the left.

**3.4.4 Functions of several variables and partial derivatives**

When looking at two dimensional graphs of demand and supply curves, it is natural to think of them as shifting in response to changes in other prices, income, and so forth. When working with demand and supply functions, it makes more sense to incorporate such factors directly into the analysis.

*Simple example:* The effect of changes in the price of pork and diesel fuel on the supply of corn might be captured by the following elaboration of equation (5):

$$s_c^*(p_c, p_p, p_d) = -543 + 300p_c - 10p_p - 7p_d. \quad (13)$$

The domain of this function involves three variables:  $p_c$  is the price of corn,  $p_p$  is the price of pork and  $p_d$  is the price of diesel fuel. This equation is a generalization of equation (5):  $S_c(p_c) = 300p - 600$ . That is to say, as a special case,  $s_c^*(p_c, p_f, p_p)$  will yield the same relationship between  $p_c$  and  $s_c$  that was captured by equation (5) and plotted in Figure 3.3 Specifically, if  $p_p = \$5.00$  and  $p_d = \$1.00$ , then  $s_c^*(p_c, 5, 1) = -543 + 300p_c - 50 - 7 = 300p_c - 600$ ; i.e.,  $s_c^*(p_c, 5, 1) = s_c(p_c)$ .

Demand may also depend on more than price. Income may be said to be a *demand curve shifter* when we are thinking in terms of a two dimensional graph. The relationship might be represented mathematically by the function

$$q(p, y) = 10 - 100p + \frac{y}{2}, \quad (14)$$

where  $q$  is quantity measured in bushels,  $p$  is price in dollars, and  $y$  is dollars of income. Then for the special case of  $y = 3,580$ , this is identical to equation (4) and obviously a \$1.00 increase in  $p$  (given  $y$ ), will again change quantity demanded by 100 bushels.

It is clear from equation (14), since it happens to be linear, that at any given level of income a dollar increase in price will reduce quantity demanded by 100 bushels. And that is exactly what the partial derivative is all about. The *partial derivative* of  $q$  with respect  $p$ , written  $\partial q / \partial p$ , looks at the change in  $q$  if  $p$  changes while the other variable(s) (e.g., income) remain constant — it is like a *controlled experiment*. Similarly, the partial derivative of  $q$  with respect to  $y$ , written  $\partial q / \partial y$  looks at the change in  $q$  with response to a change in  $y$ , holding  $p$  constant. We have *two* partials for demand equation (14) because  $q$  depends on two variables,  $p$  and  $y$ .

*Basic rule:* The partial derivative is calculated according to the usual rules of differentiation, but with the control variable (or variables) treated as constant.

Thus for equation (14) above we have two partial derivatives:

$$\frac{\partial q}{\partial p} = -100 \quad \text{and} \quad \frac{\partial q}{\partial y} = \frac{1}{2}. \quad (15)$$

Note that the partial symbol  $\partial$  (sometimes pronounced “deb’ba”) is substituted for  $d$  in order to indicate that this is a partial derivative.

*Supply and Demand: Where do prices come from?* 75

Similarly, from equation (13) we have for the effects on the supply of corn of changes in the price of pork and diesel fuel:

$$\frac{\partial s_c}{\partial p_c} = 300, \quad \frac{\partial s_c}{\partial p_p} = -10, \quad \text{and} \quad \frac{\partial s_c}{\partial p_d} = -7. \quad (16)$$

The non-linear case is slightly more interesting. First consider the demand equation

$$q(p) = 10p^{-0.5}; \quad (17)$$

then obviously,  $dq/dp = -5p^{-1.5}$ ; also, the reciprocal of  $dq/dp$  is the slope of the demand curve; i.e.,  $dp/dq = -p^{1.5}/5$ . We can add income  $y$  into equation (17), obtaining

$$q(p, y) = 10p^{-0.5} + \frac{y}{2}. \quad (18)$$

Now  $\partial q/\partial p = -5p^{-1.5}$ , just as before; also,  $\partial q/\partial y = 1/2$ . Note that in this instance the slope of the demand curve depends on price but not income. A slightly richer case is

$$q = 10p^{-0.5}y^{0.3} \quad (19)$$

with partial derivatives

$$\frac{\partial q}{\partial p} = -5p^{-1.5}y^{0.3} = -\frac{1}{2} \frac{(10p^{-0.5}y^{0.3})}{p} = -\frac{1}{2} \frac{q}{p} \quad (20)$$

(obtained by treating  $y$  as a constant, as in a controlled experiment) and

$$\frac{\partial q}{\partial y} = 3p^{-0.5}y^{-0.7} = 0.3 \frac{q}{y} \quad (21)$$

(obtained by treating  $p$  as a constant).<sup>5</sup>

### 3.5 Elasticity

The consumption of some commodities is quite sensitive to price; others less so. If the price of strawberries climbs when supply falls off near the end of the season, we can always eat cherries or watermelon instead. Because of the availability of such close substitutes, an increase in the price of strawberries may lead to a substantial reduction in the demand because consumers will

<sup>5</sup>We could write  $\partial q(p, y)/\partial y = 3p^{-0.5}y^{-0.7}$  if necessary in order to make clear which variable(s) is being held constant.