CHAPTER 11

Monopoly

Monopoly: one parrot.

A **monopoly** is the only supplier of a good for which there is no close substitute. Monopolies have been common since ancient times. In the fifth century B.C., the Greek philosopher Thales gained control of most of the olive presses during a year of exceptionally productive harvests. Similarly, the ancient Egyptian pharaohs controlled the sale of food. In England, until Parliament limited the practice in 1624, kings granted monopoly rights called royal charters or patents to court favorites. Today, virtually every country grants a *patent*—an exclusive right to sell that lasts for a limited period of time—to an inventor of a new product, process, substance, or design. Until 1999, the U.S. government gave one company the right to be the sole registrar of Internet domain names.

A monopoly can *set* its price—it is not a price taker like a competitive firm. A monopoly's output is the market output, and the demand curve a monopoly faces is the market demand curve. Because the market demand curve is downward sloping, the monopoly (unlike a competitive firm) doesn't lose all its sales if it raises its price. As a consequence, the monopoly sets its price above marginal cost to maximize its profit. Consumers buy less at this high monopoly price than they would at the competitive price, which equals marginal cost.

In this chapter, we examine seven main topics

1. **Monopoly profit maximization:** Like all firms, a monopoly maximizes its profit by setting its price or output so that its marginal revenue equals its marginal cost.
2. **Market power:** How much the monopoly's price is above its marginal cost depends on the shape of the demand curve it faces.
3. **Effects of a shift of the demand curve:** A shift of the demand curve may have a wider range of effects on a monopoly than on a competitive market.
4. **Welfare effects of monopoly:** By setting its price above marginal cost, a monopoly creates a deadweight loss.
5. **Cost advantages that create monopolies:** A firm can use a cost advantage over other firms (due, say, to control of a key input or economies of scale) to become a monopoly.
6. **Government actions that create monopolies:** Governments create monopolies by establishing government monopoly firms, limiting entry of other firms to create a private monopoly, and issuing patents, which are temporary monopoly rights.
7. **Government actions that reduce market power:** The welfare loss of a monopoly can be reduced or eliminated if the government regulates the price the monopoly charges or allows other firms to enter the market.

11.1 MONOPOLY PROFIT MAXIMIZATION

All firms, including competitive firms and monopolies, maximize their profits by setting *marginal revenue equal to marginal cost* (Chapter 8). We already know how to derive the marginal cost curve of a monopoly from its cost curve (Chapter 7). We now derive the monopoly's marginal revenue curve and then use the marginal revenue and marginal cost curves to examine the monopoly's profit-maximizing behavior.

Marginal Revenue

A firm's marginal revenue curve depends on its demand curve. We will show that a monopoly's marginal revenue curve lies below its demand curve at any positive quantity because its demand curve is downward sloping.

Marginal Revenue and Price. A firm's demand curve shows the price, p, it receives for selling a given quantity, q. The price is the *average revenue* the firm receives, so a firm's revenue is $R = pq$.

A firm's *marginal revenue*, MR, is the change in its revenue from selling one more unit. A firm that earns ΔR more revenue when it sells Δq extra units of output has a marginal revenue (Chapter 8) of

$$MR = \Delta R/\Delta q.$$

If the firm sells exactly one more unit, $\Delta q = 1$, its marginal revenue is $MR = \Delta R$.

The marginal revenue of a monopoly differs from that of a competitive firm because the monopoly faces a downward-sloping demand curve unlike the competitive firm. The competitive firm in panel a of Figure 11.1 faces a horizontal demand curve at the market price, p_1. Because its demand curve is horizontal, the competitive firm can sell another unit of output without dropping its price. As a result, the marginal revenue it receives from selling the last unit of output is the market price.

Initially, the competitive firm sells q units of output at the market price of p_1, so its revenue, R_1, is area A, which is a rectangle that is $p_1 \times q$. If the firm sells one more unit, its revenue is $R_2 = A + B$, where area B is $p_1 \times 1 = p_1$. The competitive firm's marginal revenue equals the market price:

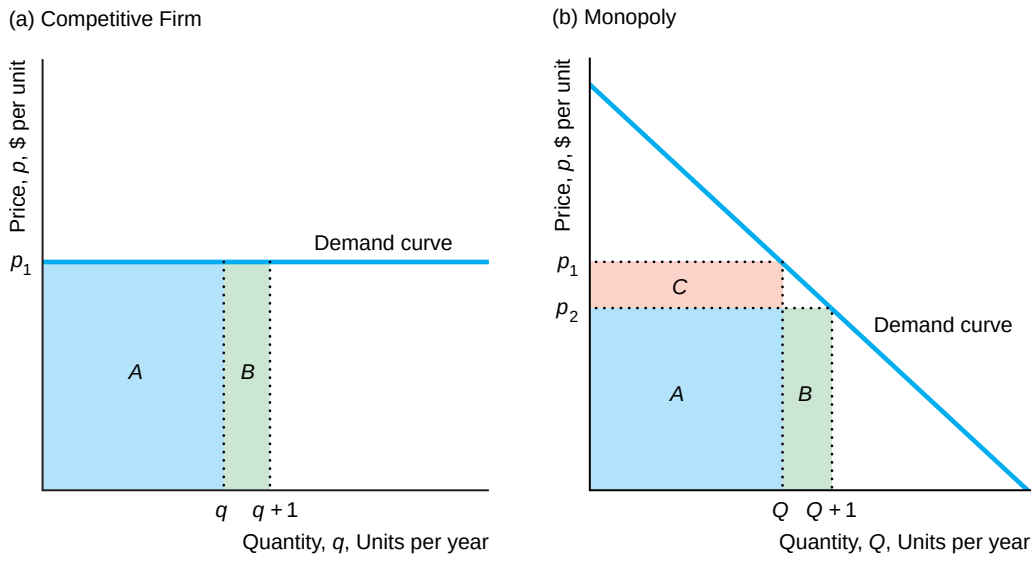
$$\Delta R = R_2 - R_1 = (A + B) - A = B = p_1.$$

A monopoly faces a downward-sloping market demand curve, as in panel b of Figure 11.1. (We've called the number of units of output a firm sells q and the output of all the firms in a market, or market output, Q. Because a monopoly is the only firm in the market, there is no distinction between q and Q, so we use Q to describe both the firm's and the market's output.) The monopoly, which is initially selling Q units at p_1, can sell one extra unit only if the price falls to p_2.

The monopoly's initial revenue, $p_1 \times Q$, is $R_1 = A + C$. When it sells the extra unit, its revenue, $p_2 \times (Q + 1)$, is $R_2 = A + B$. Thus its marginal revenue is

$$\Delta R = R_2 - R_1 = (A + B) - (A + C) = B - C.$$

The monopoly sells the extra unit of output at the new price, p_2, so its extra revenue is $B = p_2 \times 1 = p_2$. The monopoly loses the difference between the new price



	Initial Revenue, R_1	Revenue with One More Unit, R_2	Marginal Revenue, $R_2 - R_1$
Competition	A	$A + B$	$B = p_1$
Monopoly	$A + C$	$A + B$	$B - C = p_2 - C$

Figure 11.1 Average and Marginal Revenue. The demand curve shows the average revenue or price per unit of output sold. (a) The competitive firm's marginal revenue, area B, equals the market price, p_1. (b) The monopoly's marginal revenue is less than the price p_2 by area C (the revenue lost due to a lower price on the Q units originally sold).

and the original price, $\Delta p = (p_2 - p_1)$, on the Q units it originally sold: $C = \Delta p \times Q$. Thus the monopoly's marginal revenue, $B - C = p_2 - C$, is less than the price it charges by an amount equal to area C.

The competitive firm in panel a does not lose an area C from selling an extra unit because its demand curve is horizontal. It is the downward slope of the monopoly's demand curve that causes its marginal revenue to be less than its price.

Marginal Revenue Curve. Thus *the monopoly's marginal revenue curve lies below the demand curve* at every positive quantity. In general, the relationship between the marginal revenue and demand curves depends on the shape of the demand curve.

For all *linear* demand curves, the relationship between the marginal revenue and demand curve is the same. The marginal revenue curve is a straight line that starts

at the same point on the vertical (price) axis as the demand curve but has twice the slope of the demand curve, so the marginal revenue curve hits the horizontal (quantity) axis at half the quantity as the demand curve (see Appendix 11A). In Figure 11.2, the demand curve has a slope of –1 and hits the horizontal axis at 24 units, while the marginal revenue curve has a slope of –2 and hits the horizontal axis at 12 units.

★ **Deriving the Marginal Revenue Curve.** To derive the monopoly's marginal revenue curve, we write an equation summarizing the relationship between price and marginal revenue that panel b of Figure 11.1 illustrates. (Because we want this equation to hold at all prices, we drop the subscripts from the prices.) For a monopoly to increase its output by ΔQ, the monopoly lowers its price per unit by $\Delta p/\Delta Q$, which is the slope of the demand curve. By lowering its price, the monopoly loses $(\Delta p/\Delta Q) \times Q$ on the units it originally sold at the higher price (area C), but it earns an additional p on the extra output it now sells (area B). Thus the monopoly's marginal revenue is[1]

$$MR = p + \frac{\Delta p}{\Delta Q} Q. \tag{11.1}$$

Because the slope of the monopoly's demand curve, $\Delta p/\Delta Q$, is negative, the last term in Equation 11.1, $(\Delta p/\Delta Q)Q$, is negative. Equation 11.1 confirms that the price is greater than the marginal revenue, which equals p plus a negative term.

We now use Equation 11.1 to derive the marginal revenue curve when the monopoly faces the linear inverse demand function,

$$p = 24 - Q, \tag{11.2}$$

in Figure 11.2. Equation 11.2 shows that the price consumers are willing to pay falls \$1 if quantity increases by one unit. More generally, if quantity increases by ΔQ, price falls by $\Delta p = -\Delta Q$. Thus the slope of the demand curve is $\Delta p/\Delta Q = -1$.

We obtain the marginal revenue function for this monopoly by substituting into Equation 11.1 the actual slope of the demand function, $\Delta p/\Delta Q = -1$, and replacing p with $24 - Q$ (using Equation 11.2):

$$MR = p + \frac{\mathrm{D}p}{\mathrm{D}Q} Q = (24 - Q) + (-1)Q = 24 - 2Q. \tag{11.3}$$

Figure 11.2 plots Equation 11.3. The slope of this marginal revenue curve is $\Delta MR/\Delta Q = -2$, so the marginal revenue curve is twice as steeply sloped as is the demand curve.

Marginal Revenue and Price Elasticity of Demand. The marginal revenue at any given quantity depends on the demand curve's height (the price) and shape. The shape of the demand curve at a particular quantity is described by the price elasticity of

[1]Revenue is $R(Q) = p(Q)Q$, where $p(Q)$, the inverse demand function, shows how price changes as quantity increases along the demand curve. Differentiating, we find that the marginal revenue is

$$MR = \mathrm{d}R(Q)/\mathrm{d}Q = p(Q) + [\mathrm{d}p(Q)/\mathrm{d}Q]Q.$$

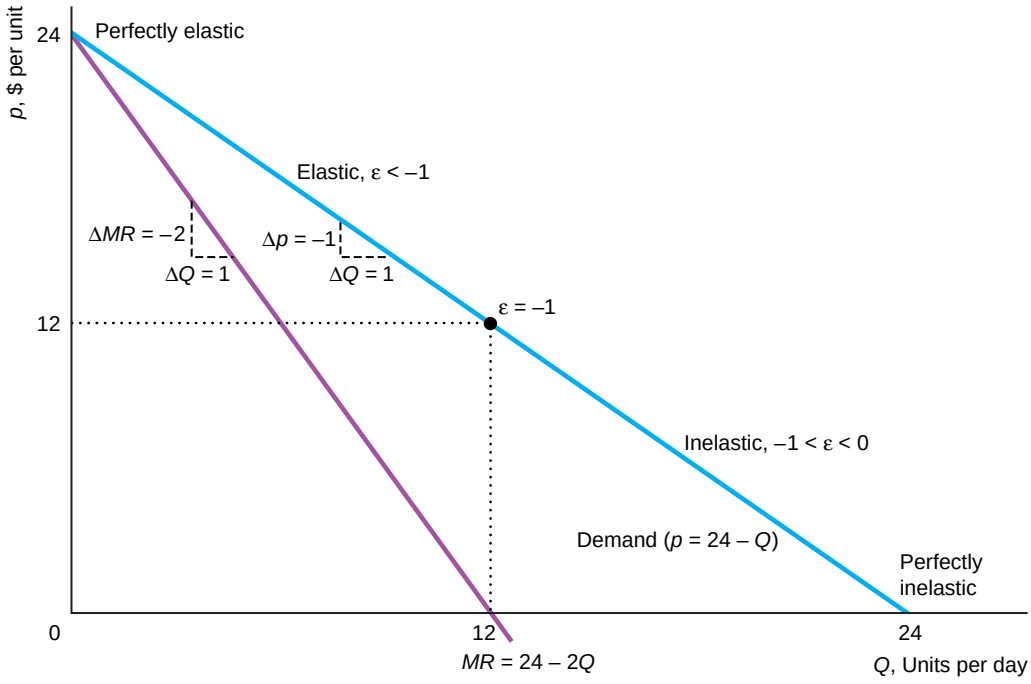


Figure 11.2 Elasticity of Demand and Total, Average, and Marginal Revenue. The demand curve (or average revenue curve), $p = 24 - Q$, lies above the marginal revenue curve, $MR = 24 - 2Q$. Where the marginal revenue equals zero, $Q = 12$, the elasticity of demand is $\varepsilon = -1$.

demand (Chapter 3), $\varepsilon = (\Delta Q/Q)/(\Delta p/p)$, which tells us the percentage by which quantity demanded falls as the price increases by 1%.

At a given quantity, the marginal revenue equals the price times a term involving the elasticity of demand:[2]

$$MR = p\left(1 + \frac{1}{\varepsilon}\right). \tag{11.4}$$

According to Equation 11.4, marginal revenue is closer to price as demand becomes more elastic. Where the demand curve hits the price axis ($Q = 0$), the

[2]By multiplying the last term in Equation 11.1 by p/p (=1) and using algebra, we can rewrite the expression as

$$MR = p + p\frac{\Delta p}{\Delta Q}\frac{Q}{p} = p\left[1 + \frac{1}{(\Delta Q / \Delta p)(p / Q)}\right].$$

The last term in this expression is $1/\varepsilon$, because $\varepsilon = (\Delta Q/\Delta p)(p/Q)$.

demand curve is perfectly elastic, so the marginal revenue equals price: $MR = p$.[3] Where the demand elasticity is unitary, $\varepsilon = -1$, marginal revenue is zero: $MR = p[1 + 1/(-1)] = 0$. Marginal revenue is negative where the demand curve is inelastic, $-1 < \varepsilon \leq 0$.

With the demand function in Equation 11.2, $\Delta Q/\Delta p = -1$, so the elasticity of demand is $\varepsilon = (\Delta Q/\Delta p)(p/Q) = -p/Q$. Table 11.1 shows the relationship among quantity, price, marginal revenue, and elasticity of demand for this linear example. As Q approaches 24, ε approaches 0, and marginal revenue is negative. As Q approaches zero, the demand becomes increasingly elastic, and marginal revenue approaches the price.

Choosing Price or Quantity

Any firm maximizes its profit by operating where its marginal revenue equals its marginal cost. Unlike a competitive firm, a monopoly can adjust its price, so it has a choice of setting its price *or* its quantity to maximize its profit. (A competitive firm sets its quantity to maximize profit because it cannot affect market price.)

The monopoly is constrained by the market demand curve. Because the demand curve slopes downward, the monopoly faces a trade-off between a higher price and a lower quantity or a lower price and a higher quantity. The monopoly chooses the

Table 11.1 Quantity, Price, Marginal Revenue, and Elasticity for the Linear Inverse Demand Curve $p = 24 - Q$

Quantity, Q	Price, p	Marginal Revenue, MR	Elasticity of Demand, $\varepsilon = -p/Q$	
0	24	24	$-\infty$	↓more elastic→
1	23	22	–23	
2	22	20	–11	
3	21	18	–7	
4	20	16	–5	
5	19	14	–3.8	
6	18	12	–3	
7	17	10	–2.43	
8	16	8	–2	
9	15	6	–1.67	
10	14	4	–1.4	
11	13	2	–1.18	
12	**12**	**0**	**–1**	
13	11	–2	–0.85	
14	10	–4	–0.71	←less elastic↑
. . .	. . .	. . .	. . .	
23	1	–22	–0.043	
24	0	–24	0	

[3] As ε approaches $-\infty$ (perfectly elastic demand), the $1/\varepsilon$ term approaches zero, so $MR = p(1 + 1/\varepsilon)$ approaches p.

point on the demand curve that maximizes its profit. Unfortunately for the monopoly, it cannot set both its quantity and its price—thereby picking a point that is above the demand curve. If it could do so, the monopoly would choose an extremely high price and an extremely high output level and would become exceedingly wealthy.

If the monopoly sets its price, the demand curve determines how much output it sells. If the monopoly picks an output level, the demand curve determines the price. Because the monopoly wants to operate at the price and output at which its profit is maximized, it chooses the same profit-maximizing solution whether it sets the price or output. In the following, we assume that the monopoly sets quantity.

Graphical Approach

All firms, including monopolies, use a two-step analysis to determine the output level that maximizes its profit (Chapter 8). First, the firm determines the output, Q^*, at which it makes the highest possible profit—the output at which its marginal revenue equals its marginal cost. Second, the firm decides whether to produce Q^* or shut down.

Profit-Maximizing Output. To illustrate how a monopoly chooses its output to maximize its profit, we continue to use the same linear demand and marginal revenue curves but add a linear marginal cost curve in panel a of Figure 11.3. Panel b shows the corresponding profit curve. The profit curve reaches its maximum at 6 units of output, where marginal profit—the slope of the profit curve—is zero. Because *marginal profit is marginal revenue minus marginal cost* (Chapter 8), marginal profit is zero where marginal revenue equals marginal cost. In panel a, marginal revenue equals marginal cost at 6 units. The price on the demand curve at that quantity is \$18. Thus the monopoly maximizes its profit at point *e*, where it sells 6 units per day for \$18 each.

Why does the monopoly maximize its profit by producing 6 units where its marginal revenue equals its marginal cost? At smaller quantities, the monopoly's marginal revenue is greater than its marginal cost, so its marginal profit is positive. By increasing its output, it raises its profit. Similarly, at quantities greater than 6 units, the monopoly's marginal cost is greater than its marginal revenue, so it can increase its profit by reducing its output.

The profit-maximizing quantity is smaller than the revenue-maximizing quantity. The revenue curve reaches its maximum at $Q = 12$, where the slope of the revenue curve, the marginal revenue, is zero (panel a). In contrast, the profit curve reaches its maximum at $Q = 6$, where marginal revenue equals marginal cost. Because marginal cost is positive, marginal revenue must be positive where profit is maximized. Because the marginal revenue curve has a negative slope, marginal revenue is positive at a smaller quantity than where it equals zero. Thus the profit curve must reach a maximum at a smaller quantity, 6, than the revenue curve, 12.

As we already know, marginal revenue equals zero at the quantity where the demand curve has a unitary elasticity. Because a linear demand curve is more elastic at smaller quantities, *monopoly profit is maximized in the elastic portion of the demand curve*. (Here profit is maximized at $Q = 6$ where the elasticity of demand is –3.) Equivalently, *a monopoly never operates in the inelastic portion of its demand curve*.

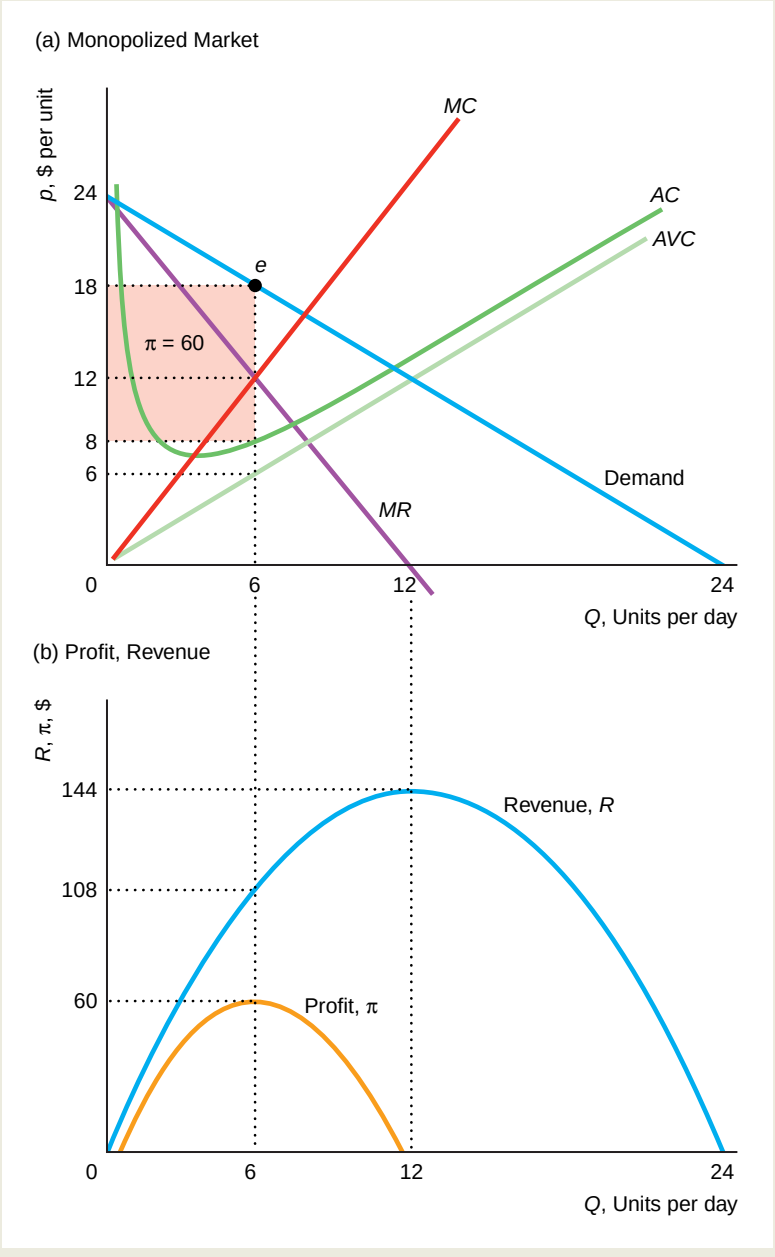


Figure 11.3 Maximizing Profit. (a) At $Q = 6$, where marginal revenue, MR, equals marginal cost, MC, profit is maximized. The rectangle showing the maximum profit \$60 is average profit per unit, $p - AC = \$18 - \$8 = \$10$, times the number of units, 6. (b) Profit is maximized at a smaller quantity, $Q = 6$ (where marginal revenue equals marginal cost), than is revenue, $Q = 12$ (where marginal revenue is zero).

Shutdown Decision. A monopoly shuts down to avoid making a loss in the long run if the monopoly-optimal price is below its average cost. In the short run, the monopoly shuts down if the monopoly-optimal price is less than its average variable cost. In our short-run example in Figure 11.3, the average variable cost, $AVC = \$6$, is less than the price, $p = \$18$, at the profit-maximizing output, $Q = 6$, so the firm chooses to produce.

Price is also above average cost at $Q = 6$, so the monopoly makes a positive profit.[4] At the profit-maximizing quantity of 6 units, the price is $p(6) = \$18$ and the average cost is $AC(6) = \$8$. As a result, the profit, $\pi = \$60$, is the shaded rectangle with a height equal to the average profit per unit, $p(6) - AC(6) = \$18 - \$8 = \$10$, and a width of 6 units.

Mathematical Approach

We can also solve for the profit-maximizing quantity mathematically. We already know the demand and marginal revenue functions for this monopoly. We need to determine its marginal cost curve. The monopoly's cost is a function of its output, $C(Q)$. In Figure 11.3, we assume that the monopoly faces a short-run cost function of

$$C(Q) = Q^2 + 12, \tag{11.5}$$

where Q^2 is the monopoly's variable cost as a function of output and \$12 is its fixed cost (Chapter 7). Given this cost function, the monopoly's marginal cost function is[5]

$$MC = 2Q. \tag{11.6}$$

This marginal cost curve is a straight line through the origin with a slope of 2 in panel a. The average variable cost is $AVC = Q^2/Q = Q$, so it is a straight line through the origin with a slope of 1. The average cost is $AC = C/Q = (Q^2 + 12)/Q = Q + 12/Q$, which is U-shaped.

We determine the profit-maximizing output by equating the marginal revenue (Equation 11.3) and marginal cost (Equation 11.6) functions:

$$MR = 24 - 2Q = 2Q = MC.$$

Solving for Q, we find that $Q = 6$. Substituting $Q = 6$ into the inverse demand function (Equation 11.2), we find that the profit-maximizing price is

$$p = 24 - Q = 24 - 6 = \$18.$$

At that quantity, the average variable cost is $AVC = \$6$, which is less than the price, so the firm does not shut down. The average cost is $AC = \$(6 + 12/6) = \$8$, which is less than the price, so the firm makes a profit.

---

[4]Because profit is $\pi = p(Q)Q - C(Q)$, average profit is $\pi/Q = p(Q) - C(Q)/Q = p(Q) - AC$. Thus average profit (and hence profit) is positive only if price is above average cost.

[5]By differentiating Equation 11.5 with respect to output, we find that the marginal cost is $MC = dC(Q)/dQ = 2Q$.

11.2 MARKET POWER

A monopoly has **market power**: the ability of a firm to charge a price above marginal cost and earn a positive profit. We now examine the factors that determine how much above its marginal cost a monopoly sets its price.

Market Power and the Shape of the Demand Curve

The degree to which the monopoly raises its price above its marginal cost depends on the shape of the demand curve at the profit-maximizing quantity. If the monopoly faces a highly elastic—nearly flat—demand curve at the profit-maximizing quantity, it would lose substantial sales if it raised its price by even a small amount. Conversely, if the demand curve is not very elastic (relatively steep) at that quantity, the monopoly would lose fewer sales from raising its price by the same amount.

We can derive the relationship between market power and the elasticity of demand at the profit-maximizing quantity using the expression for marginal revenue in Equation 11.4 and the firm's profit-maximizing condition that marginal revenue equals marginal cost:

$$MR = p\left(1 + \frac{1}{\varepsilon}\right) = MC. \tag{11.7}$$

By rearranging terms, we can rewrite Equation 11.7 as

$$\frac{p}{MC} = \frac{1}{1 + (1 / \varepsilon)}. \tag{11.8}$$

Equation 11.8 says that the ratio of the price to marginal cost depends *only* on the elasticity of demand at the profit-maximizing quantity.

In our linear demand example in panel a of Figure 11.3, the elasticity of demand is $\varepsilon = -3$ at the monopoly optimum where $Q = 6$. As a result, the ratio of price to marginal cost is $p/MC = 1/[1 + 1/(-3)] = 1.5$, or $p = 1.5MC$. The profit-maximizing price, \$18, in panel a is 1.5 times the marginal cost of \$12.

Table 11.2 illustrates how the ratio of price to marginal cost varies with the elasticity of demand. When the elasticity is –1.01, only slightly elastic, the monopoly's profit-maximizing price is 101 times larger than its marginal cost: $p/MC = 1/[1 + 1/(-1.01)] \approx 101$. As the elasticity of demand approaches negative infinity (becomes perfectly elastic), the ratio of price to marginal cost shrinks to $p/MC = 1$.[6]

This table illustrates that not all monopolies can set high prices. A monopoly that faces a horizontal, perfectly elastic demand curve, sets its price equal to its marginal cost—just like a price-taking, competitive firm. If this monopoly were to raise its price, it would lose all its sales, so it maximizes its profit by setting its price equal to its marginal cost.

The more elastic the demand curve, the less a monopoly can raise its price without losing sales. All else the same, the more close substitutes for the monopoly's good there are, the more elastic the demand the monopoly faces. For example, Addison Wesley Longman has the monopoly right to produce and sell this textbook. Many other publishers, however, have the rights to produce and sell similar micro-

[6]As the elasticity approaches negative infinity, $1/\varepsilon$ approaches zero, so $1/(1 + 1/\varepsilon)$ approaches $1/1 = 1$.

Table 11.2 Elasticity of Demand, Price, and Marginal Cost

	Elasticity of Demand, ε	Price/Marginal Cost Ratio, $p/MC = 1/[1 + (1/\varepsilon)]$	Lerner Index, $(p - MC)/p = -1/\varepsilon$
←more elastic less elastic→	–1.01	101	0.99
	–1.1	11	0.91
	–2	2	0.5
	–3	1.5	0.33
	–5	1.25	0.2
	–10	1.11	0.1
	–100	1.01	0.01
	$-\infty$	1	0

economics textbooks (though you wouldn't like them as much). The demand Addison Wesley Longman faces is much more elastic than it would be if no substitutes were available. If you think this textbook is expensive, imagine what it would cost if no substitutes were published!

Lerner Index

Another way to show how the elasticity of demand affects a monopoly's price relative to its marginal cost is to look at the firm's **Lerner Index** (or *price markup*):[7] the ratio of the difference between price and marginal cost to the price: $(p - MC)/p$. This measure is zero for a competitive firm because a competitive firm cannot raise its price above its marginal cost. The greater the difference between price and marginal cost, the larger the Lerner Index and the greater the monopoly's ability to set price above marginal cost.

We can express the Lerner Index in terms of the elasticity of demand by rearranging Equation 11.8:

$$\frac{p - MC}{p} = -\frac{1}{\varepsilon}. \tag{11.9}$$

Because $MC \geq 0$ and $p \geq MC$, $0 \leq p - MC \leq p$, so the Lerner Index ranges from 0 to 1 for a profit-maximizing firm.[8] Equation 11.9 confirms that a competitive firm has a Lerner Index of zero because its demand curve is perfectly elastic.[9] As Table 11.2 illustrates, the Lerner Index for a monopoly increases as the demand becomes less elastic. If $\varepsilon = -5$, the monopoly's markup (Lerner Index) is $1/5 = 0.2$; if $\varepsilon = -2$,

[7]This index is named after Abba Lerner, the economist who invented it.

[8]For the Lerner Index to be above 1, ε would have to be a negative fraction, indicating that the demand curve was inelastic at the monopoly optimum. However, a profit-maximizing monopoly never operates in the inelastic portion of its demand curve.

[9]As the elasticity of demand approaches negative infinity, the Lerner Index, $-1/\varepsilon$, approaches zero.

the markup is 1/2 = 0.5; and if $\varepsilon = -1.01$, the markup is 0.99. Monopolies that face demand curves that are only slightly elastic set prices that are multiples of their marginal cost and have Lerner Indexes close to 1.

Application

HUMANA HOSPITALS

As the table shows, Humana hospitals in 1991 had very large price–marginal cost ratios and Lerner Indexes close to 1 on many supplies they sell to patients, apparently because they faced elasticities of demand close to –1. For example,

	Price Charged Patients, p	Hospitals' Marginal Cost, MC	p/MC	Implicit Demand Elasticity, ε	Lerner Index
Saline solution	$44.90	$0.81	55.4	–1.02	0.98
Rubber arm pads for crutches	$23.75	$0.90	26.4	–1.04	0.96
Rubber tips for crutches	$15.95	$0.71	22.5	–1.05	0.96
Heating pad	$118.00	$5.74	20.6	–1.05	0.95
Pair of crutches	$103.65	$8.35	12.4	–1.09	0.92
Esophagus tube	$1,205.50	$151.98	7.9	–1.14	0.87
Average, all supplies			2.3	–1.77	0.57

Humana's Suburban Hospital in Louisville charged patients $44.90 for a container of saline solution (salt water) that cost the hospital 81¢, so its price was more than 55 times higher than its marginal cost, implying a price elasticity of –1.02 and a Lerner Index of 0.98, which is close to the theoretical maximum. Although the table highlights some of the extreme cases—the price–marginal cost ratio for supplies averages "only" 2.3—at least it doesn't show the markups at some of their hospitals on $9 Tylenol tablets and $455 nursing bras.

Sources of Market Power

When will a monopoly face a relatively elastic demand curve and hence have little market power? Ultimately, the elasticity of demand of the market demand curve depends on consumers' tastes and options. The more consumers want a good—the more willing they are to pay "virtually anything" for it—the less elastic is the demand curve.

All else the same, the demand curve a firm (not necessarily a monopoly) faces becomes more elastic as *better substitutes* for the firm's product are introduced, *more firms* enter the market selling the same product, or firms that provide the same service *locate closer* to this firm. The demand curves for Xerox, the U.S. Postal Service, and McDonald's have become more elastic in recent decades for these three reasons.

When Xerox started selling its plain-paper copier, no other firm sold a close substitute. Other companies' machines produced copies on special slimy paper that yellowed quickly. As other firms developed plain-paper copiers, the demand curve that Xerox faced became more elastic.

The U.S. Postal Service (USPS) has a monopoly in first-class mail service. Today, phone calls, faxes, and e-mail are excellent substitutes for many types of first-class mail. The USPS had a monopoly in overnight delivery services until 1979. Now

Federal Express, United Parcel Service, and many other firms compete with the USPS in providing overnight deliveries. Because of this new competition, the USPS's share of business and personal correspondence fell from 77% in 1988 to 59% in 1996, and its overnight-mail market fell to 4%.[10] Thus over time the demand curves the USPS faces for first-class mail and overnight service have shifted downward and become more elastic.

As you drive down a highway, you may notice that McDonald's restaurants are spaced miles apart. The purpose of this spacing is to reduce the likelihood that two McDonald's outlets will compete for the same customer. Although McDonald's can prevent its own restaurants from competing with each other, it cannot prevent Wendy's or Burger King from locating near its restaurants. As other fast-food restaurants open near a McDonald's, that restaurant faces a more elastic demand.

What happens as a profit-maximizing monopoly faces more elastic demand? It has to lower its price. See **www.aw.com/perloff**, Chapter 11, "Airport Monopolies" for an illustration of how a monopoly adjusts its price as it changes its beliefs about the elasticity of demand it faces.

⋆11.3 EFFECTS OF A SHIFT OF THE DEMAND CURVE

Shifts in the demand curve or marginal cost curve affect the monopoly optimum and can have a wider variety of effects in a monopolized market than in a competitive market. In a competitive market, the effect of a shift in demand on a competitive firm's output depends only on the shape of the marginal cost curve (Chapter 8). In contrast, the effect of a shift in demand on a monopoly's output depends on the shapes of both the marginal cost curve and the demand curve.

As we saw in Chapter 8, a competitive firm's marginal cost curve tells us everything we need to know about the amount that firm will supply at any given market price. The competitive firm's supply curve is its upward-sloping marginal cost curve (above its minimum average variable cost). A competitive firm's supply behavior does not depend on the shape of the market demand curve because it always faces a horizontal demand curve at the market price. Thus if you know a competitive firm's marginal cost curve, you can predict how much that firm will produce at any given market price.

In contrast, a monopoly's output decision depends on the shapes of its marginal cost curve and its demand curve. Unlike a competitive firm, *a monopoly does not have a supply curve*. Knowing the monopoly's marginal cost curve is not enough for us to predict how much a monopoly will sell at any given price.

Figure 11.4 illustrates that the relationship between price and quantity is unique in a competitive market but not in a monopoly market. If the market is competitive, the initial equilibrium is e_1 in panel a, where the original demand curve D^1 intersects the supply curve, MC, which is the sum of the marginal cost curves of a large number of competitive firms. When the demand curve shifts to D^2, the new competitive equilibrium, e_2, has a higher price and quantity. A shift of the demand curve maps

[10]Passell, Peter, "Battered by Its Rivals," *New York Times*, May 15, 1997:C1.

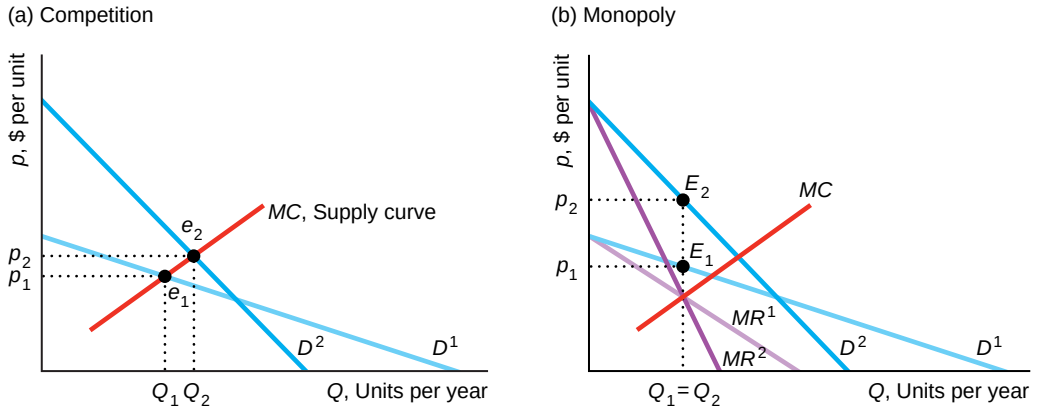


Figure 11.4 Effects of a Shift of the Demand Curve. (a) A shift of the demand curve from D^1 to D^2 causes the competitive equilibrium to move from e_1 to e_2 along the supply curve (the horizontal sum of the marginal cost curves of all the competitive firms). Because the competitive equilibrium lies on the supply curve, each quantity corresponds to only one possible equilibrium price. (b) With a monopoly, this same shift of demand causes the monopoly optimum to change from E_1 to E_2. The monopoly quantity stays the same, but the monopoly price rises. Thus a shift in demand does not map out a unique relationship between price and quantity in a monopolized market: The same quantity, $Q_1 = Q_2$, is associated with two different prices, p_1 and p_2.

out competitive equilibria along the marginal cost curve, so for every equilibrium quantity, there is a single corresponding equilibrium price.

Now suppose there is a monopoly. As demand shifts from D^1 to D^2, the monopoly optimum shifts from E_1 to E_2 in panel b, so the price rises but the quantity stays constant, $Q_1 = Q_2$. Thus *a given quantity can correspond to more than one monopoly-optimal price*. A shift in the demand curve may cause the monopoly-optimal price to stay constant and the quantity to change or both price and quantity to change.

11.4 WELFARE EFFECTS OF MONOPOLY

Welfare, W (here defined as the sum of consumer surplus, CS, and producer surplus, PS), is lower under monopoly than under competition. Chapter 9 showed that competition maximizes welfare because price equals marginal cost. By setting its price above its marginal cost, a monopoly causes consumers to buy less than the competitive level of the good, so a deadweight loss to society occurs.

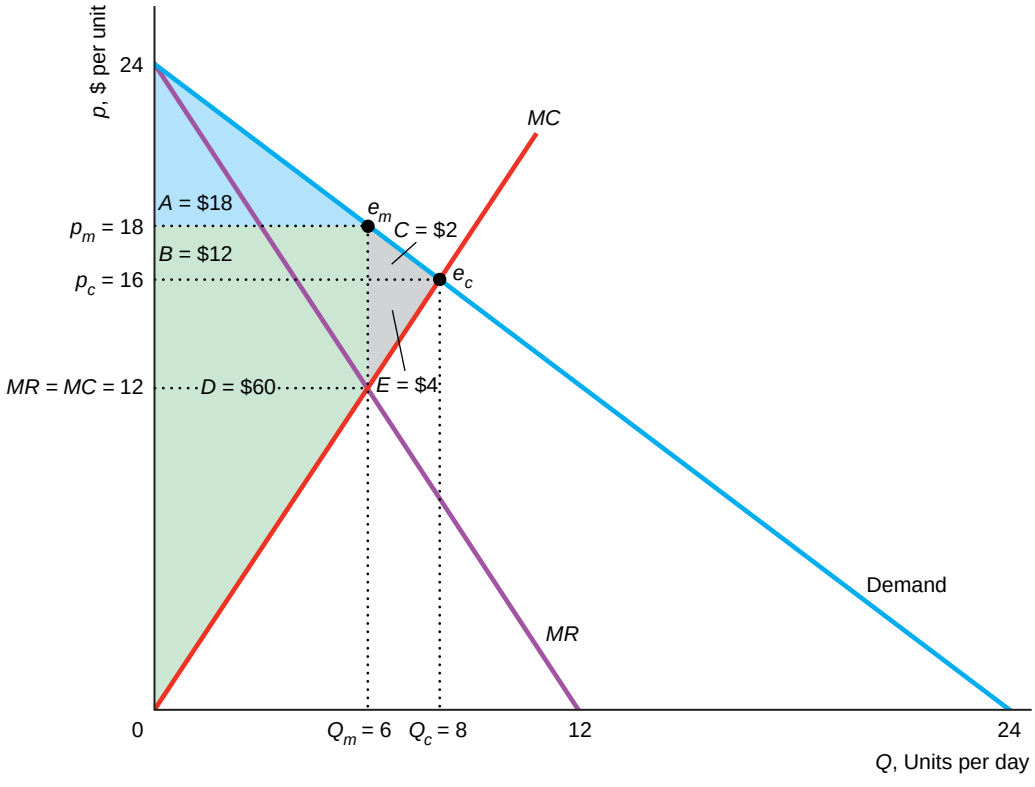
Graphing the Welfare Loss

We illustrate this loss using our continuing example. If the monopoly were to act like a competitive market and operate where its inverse demand curve, Equation 11.2, intersects its marginal cost (supply) curve, Equation 11.6,

$$p = 24 - Q = 2Q = MC,$$

it would sell $Q_c = 8$ units of output at a price of \$16, as in Figure 11.5. At this competitive price, consumer surplus is area $A + B + C$ and producer surplus is $D + E$.

If the firm acts like a monopoly and operates where its marginal revenue equals its marginal cost, only 6 units are sold at the monopoly price of \$18, and consumer



	Competition	Monopoly	Change
Consumer Surplus, *CS*	$A + B + C$	A	$-B - C = \Delta CS$
Producer Surplus, *PS*	$D + E$	$B + D$	$B - E = \Delta PS$
Welfare, $W = CS + PS$	$A + B + C + D + E$	$A + B + D$	$-C - E = \Delta W = DWL$

Figure 11.5 Deadweight Loss of Monopoly. A competitive market would produce $Q_c = 8$ at $p_c =$ \$16, where the demand curve intersects the marginal cost (supply) curve. A monopoly produces only $Q_m = 6$ at $p_m =$ \$18, where the marginal revenue curve intersects the marginal cost curve. Under monopoly, consumer surplus is A, producer surplus is $B + D$, and the lost welfare or deadweight loss of monopoly is $-C - E$.

surplus is only A. Part of the lost consumer surplus, B, goes to the monopoly; but the rest, C, is lost.

By charging the monopoly price of \$18 instead of the competitive price of \$16, the monopoly receives \$2 more per unit and earns an extra profit of area B = \$12 on the Q_m = 6 units it sells. The monopoly loses area E, however, because it sells less than the competitive output. Consequently, the monopoly's producer surplus increases by $B - E$ over the competitive level. We know that its producer surplus increases, $B - E > 0$, because the monopoly had the option of producing at the competitive level and chose not to do so.

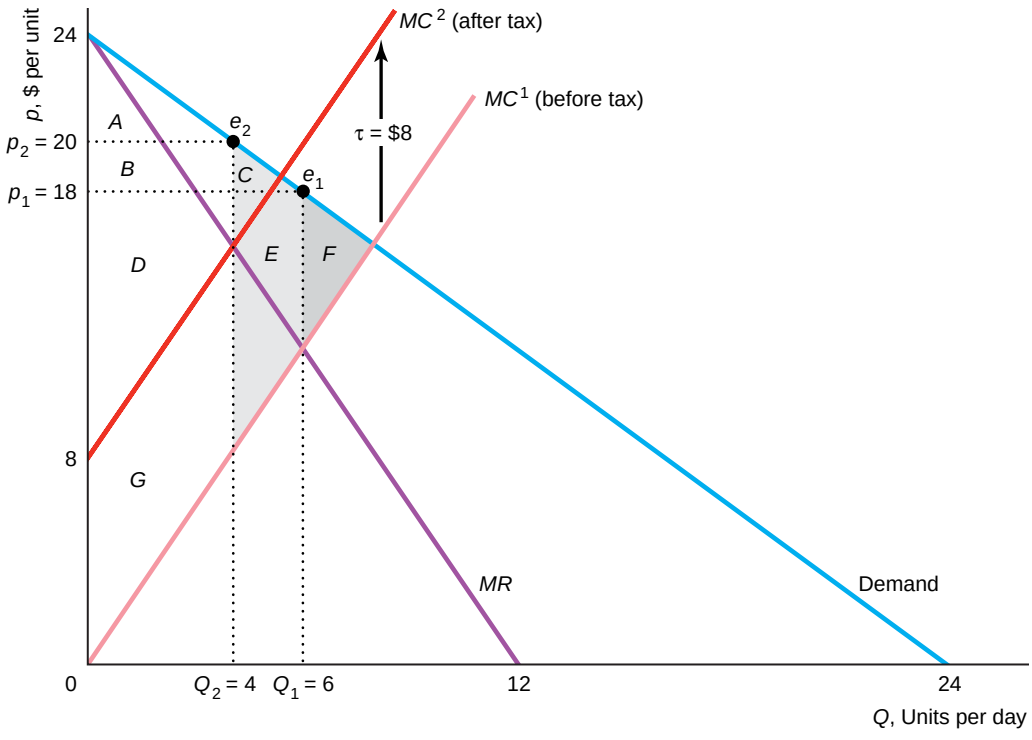
Monopoly welfare is lower than competitive welfare. The deadweight loss of monopoly is $-C - E$, which represents the consumer surplus and producer surplus lost because less than the competitive output is produced. As in the analysis of a tax in Chapter 9, the deadweight loss is due to the gap between price and marginal cost at the monopoly output. At Q_m = 6, the price, \$18, is above the marginal cost, \$12, so consumers are willing to pay more for the last unit of output than it costs to produce it. The calculated "Deadweight Loss of the U.S. Postal Service" is discussed in **www.aw.com/perloff**, Chapter 11.

Solved Problem 11.1

In our linear example, how does charging the monopoly a specific tax of τ = \$8 per unit affect the monopoly optimum and the welfare of consumers, the monopoly, and society (where society's welfare includes the tax revenue)? What is the incidence of the tax on consumers?

Answer

1. *Determine how imposing the tax affects the monopoly optimum*: In the accompanying graph, the intersection of the marginal revenue curve, MR, and the before-tax marginal cost curve, MC^1, determines the monopoly optimum quantity, Q_1 = 6. At the before-tax optimum, e_1, the price is p_1 = \$18. The specific tax causes the monopoly's before-tax marginal cost curve, $MC^1 = 2Q$, to shift upward by \$8 to $MC^2 = MC^1 + 8 = 2Q + 8$. After the tax is applied, the monopoly operates where $MR = 24 - 2Q = 2Q + 8 = MC^2$. In the after-tax monopoly optimum, e_2, the quantity is Q_2 = 4 and the price is p_2 = \$20. Thus output falls by ΔQ = 2 units and the price increases by Δp = \$2.
2. *Calculate the change in the various welfare measures*: The graph shows how the welfare measures change. Area G is the tax revenue collected by the government, τQ = \$32, because its height is the distance between the two marginal cost curves, τ = \$8, and its width is the output the monopoly produces after the tax is imposed, Q = 4. The tax reduces consumer and producer surplus and increases the deadweight loss. We know that producer surplus falls because (a) the monopoly could have produced this reduced output level in the absence of the tax but did not because it was not the profit-maximizing output, so its before-tax profit falls, and (b) the monopoly must now pay taxes. The before-tax deadweight loss from monopoly is $-F$. The



	Monopoly Before Tax	Monopoly After Tax	Change
Consumer Surplus, *CS*	$A + B + C$	A	$-B - C = \Delta CS$
Producer Surplus, *PS*	$D + E + G$	$B + D$	$B - E - G = \Delta PS$
Tax Revenues, $T = \tau Q$	0	G	$G = \Delta T$
Welfare, $W = CS + PS + T$	$A + B + C + D + E + G$	$A + B + D + G$	$-C - E = \Delta W$
Deadweight Loss, *DWL*	$-F$	$-C - E - F$	$-C - E = \Delta DWL$

after-tax deadweight loss is $-C - E - F$, so the increase in deadweight loss due to the tax is $-C - E$. The table below the graph shows that consumer surplus changes by $-B - C$ and producer surplus by $B - E - G$.

3. *Calculate the incidence of the tax*: Because the tax goes from \$0 to \$8, the change in the tax is $\Delta\tau = \$8$. The incidence of the tax (Chapter 3) on consumers is $\Delta p/\Delta\tau = \$2/\$8 = \frac{1}{4}$. (The monopoly absorbs \$6 of the tax and passes on only \$2.)[11]

[11]In contrast to a competitive market, when a monopoly is taxed, the incidence of the tax on consumers can exceed 100%, as Appendix 11B demonstrates.

Application

COMPETITIVE VS. MONOPOLY SUGAR TAX INCIDENCE

Contrary to many people's intuition, the incidence of a tax on consumers may be less for a monopolized than a competitive market. In 1996, Florida voted on (and rejected) a 1¢-per-pound excise tax on refined cane sugar in the Florida Everglades Agricultural Area. Swinton and Thomas (2001) used linear supply and demand curves (based on elasticities estimated by Marks, 1993) to calculate the incidence from this tax given that the market is competitive. They concluded that the incidence falling on purchasers is 70%.

Now suppose that the producers joined together to form a monopoly. How would the incidence falling on demanders change? Using their linear demand and supply curves, we find that the incidence falls to 41%. Thus, a competitive Florida sugar industry passes on substantially more of the tax to demanders than it would if the industry were monopolized.

★ Welfare Effects of *Ad Valorem* Versus Specific Taxes

Solved Problem 11.1 illustrates that a specific sales tax (the monopoly pays the government τ dollars per unit sold) provides tax revenue but reduces welfare below even the monopoly level. Governments use *ad valorem* taxes more often than specific taxes. Is there an advantage to using an *ad valorem* sales tax (the monopoly pays αp per unit of output, where α is a fraction and p is the price charged)? The answer is that a government raises more tax revenue with an *ad valorem* tax applied to a monopoly than with a specific tax when α and τ are set so that the after-tax output is the same with either tax, as we now show.[12]

In Figure 11.6, the before-tax market demand curve is D, and the corresponding marginal revenue is MR. The before-tax monopoly optimum is e_1. The MR curve intersects the MC curve at Q_1 units, which sell at a price of p_1.

If the government imposes a specific tax τ, the monopoly's after-tax demand curve is D^s, which is the market demand curve D shifted downward by τ dollars.[13] The corresponding marginal revenue curve, MR^s, intersects the marginal cost curve at Q_2. In this after-tax equilibrium, e_2, consumers pay p_2 and the monopoly receives $p_s = p_2 - \tau$ per unit. The government's revenue from the specific tax is area $A = \tau Q_2$.

If the government imposes an *ad valorem* tax α, the demand curve facing the monopoly is D^a. The gap between D^a and D, which is the tax per unit, αp, is greater at higher prices. By setting α appropriately, the corresponding marginal revenue

[12]Chapter 3 shows that both taxes raise the same tax revenue in a competitive market. The taxes raise different amounts when applied to monopolies or other noncompetitive firms. See Delipalla and Keen (1992), Skeath and Trandel (1994), and Hamilton (1999).

[13]Instead, we could capture the effect of a specific tax by shifting the marginal cost curve upward by τ, as in our answer to Solved Problem 11.1.

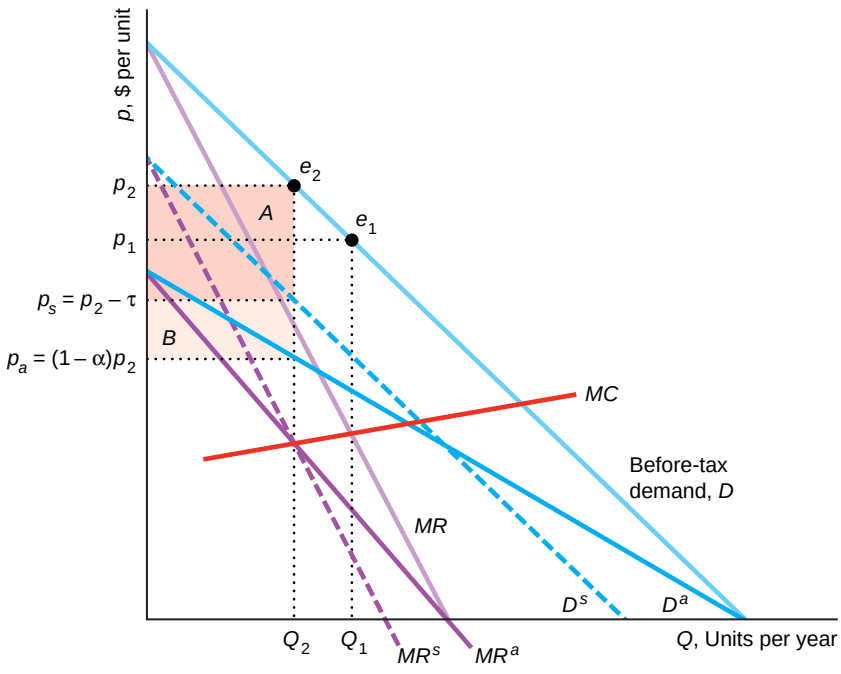


Figure 11.6 Ad Valorem Versus Specific Tax. A specific tax (τ) and an *ad valorem* tax (α) that reduce the monopoly output by the same amount (from Q_1 to Q_2) raise different amounts of tax revenues for the government. The tax revenue from the specific tax is area $A = \tau Q_2$. The tax revenue from the *ad valorem* tax is $A + B = \alpha p_2 Q_2$.

curve, MR_a, intersects the marginal cost curve at Q_2, where consumers again pay p_2. Although the *ad valorem* tax reduces output by the same amount as the specific tax, the *ad valorem* tax raises more revenue, areas $A + B = \alpha p_2 Q_2$.

Both sales taxes harm consumers by the same amount because they raise the price consumers pay from p_1 to p_2 and reduce the quantity purchased from Q_1 to Q_2. The *ad valorem* tax transfers more revenue from the monopoly to the government, so the government prefers the *ad valorem* tax and the monopoly prefers the specific tax. (Equivalently, if the government set τ and α so that they raised the same amount of tax revenue, the *ad valorem* tax would reduce output and consumer surplus less than the specific tax.) Amazingly, it makes sense for government to employ an *ad valorem* tax, and most state and local governments use *ad valorem* taxes for most goods.[14]

[14]However, as Professor Stearns and his students at the University of Maryland inform me, the federal government uses many specific taxes (alcohol, tobacco products, gasoline and other fuels, international air travel, tires, vaccines, ship passengers, ozone-depleting chemicals) as well as *ad valorem* taxes (telephone service, transportation of property by air, sports fishing equipment, bows and arrow components, gas-guzzler autos, foreign insurance, and firearms).

11.5 COST ADVANTAGES THAT CREATE MONOPOLIES

Why are some markets monopolized? Two key reasons are that a firm has a cost advantage over other firms or that a government created the monopoly.[15] If a low-cost firm profitably sells at a price so low that other potential competitors with higher costs would make losses, no other firm enters the market.

Sources of Cost Advantages

A firm can have a cost advantage over potential rivals for a number of reasons. One reason is that the firm controls a key input.[16] For example, a firm that owns the only quarry in a region is the only firm that can profitably sell gravel to local construction firms.

A second important reason why a firm may have lower costs is that the firm uses a superior technology or has a better way of organizing production. Henry Ford's methods of organizing production using assembly lines and standardization allowed him to produce cars at lower cost than rival firms until they copied his organizational techniques.

When a firm develops a better production method that provides an advantage—possibly enough of an advantage for the firm to be a monopoly—the firm must either keep the information secret or obtain a patent, which provides government protection from imitation. According to a survey of 650 research and development managers of U.S. firms (Levin, Klevorick, Nelson, and Winter, 1987), secrecy is more commonly used than patents to prevent duplication of new or improved processes by other firms but less commonly used to protect new products.

Natural Monopoly

A market has a **natural monopoly** if one firm can produce the total output of the market at lower cost than several firms could.[17] With a natural monopoly, it is more efficient to have only one firm produce than more firms. Believing that they are natural monopolies, governments frequently grant monopoly rights to *public utilities* to provide essential goods or services such as water, gas, electric power, or mail delivery.

If a firm has economies of scale (Chapter 7) at all levels of output, its average cost curve falls as output increases for any observed level of output. If all potential firms

---

[15]In later chapters, we discuss three other means by which monopolies are created. One method is the merger of several firms into a single firm (Chapter 13). This method creates a monopoly if new firms fail to enter the market. A second method is for firms to coordinate their activities and set their prices as a monopoly would (Chapter 13). Firms that act collectively in this way are called a *cartel*. A third method is for a monopoly to use strategies that discourage other firms from entering the market (Chapter 14).

[16]Chapter 14 discusses in greater detail how one firm may control an *essential facility*: a scarce resource that a rival needs to use to survive.

[17]If the cost for Firm i to produce q_i is $C(q_i)$, the condition for a natural monopoly is

$$C(Q) < C(q_1) + C(q_2) + \cdots + C(q_n),$$

where $Q = q_1 + q_2 + \cdots + q_n$ is the sum of the output of any $n \geq 2$ firms.

have the same strictly declining average cost curve, this market has a natural monopoly, as we now illustrate.[18]

A company that supplies water to homes incurs a high fixed cost, F, to build a plant and connect houses to the plant. The firm's marginal cost, m, of supplying water is constant, so its marginal cost curve is horizontal and its average cost, $AC = m + F/Q$, declines as output rises.

Figure 11.7 shows such marginal and average cost curves where m = \$10 and F = \$60. If the market output is 12 units per day, one firm produces that output at an average cost of \$15, or a total cost of \$180 (= \$15 × 12). If two firms each produce 6 units, the average cost is \$20 and the cost of producing the market output is \$240 (= \$20 × 12), which is greater than the cost with a single firm.

If the two firms divided total production in any other way, their cost of production would still exceed the cost of a single firm (as the following question asks you to prove). The reason is that the marginal cost per unit is the same no matter how

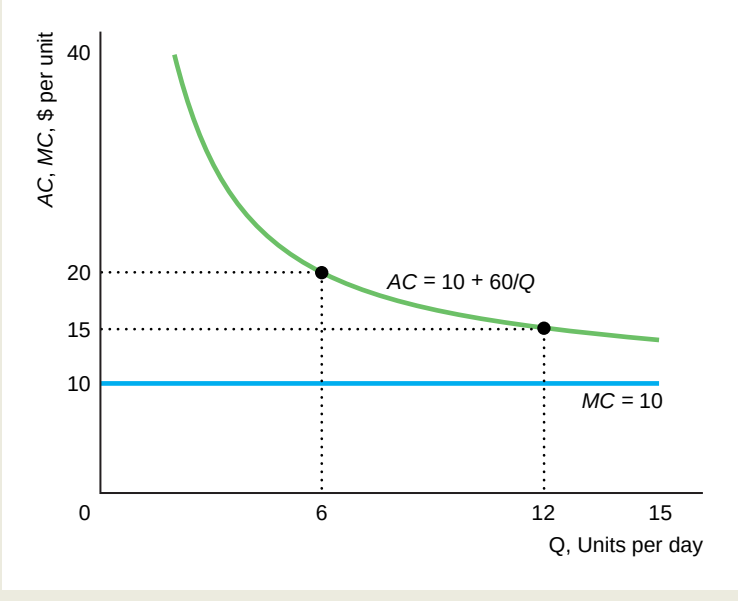


Figure 11.7 Natural Monopoly. This natural monopoly has a strictly declining average cost.

[18]A firm may be a natural monopoly even if its cost curve does not fall at all levels of output. If a U-shaped average cost curve reaches its minimum at 100 units of output, it may be less costly for only one firm to produce an output of 101 units even though average cost is rising at that output. Thus a cost function with economies of scale everywhere is a sufficient but not a necessary condition for natural monopoly.

many firms produce, but each additional firm adds a fixed cost, which raises the cost of producing a given quantity. If only one firm provides water, the cost of building a second plant and a second set of pipes is avoided.

Solved Problem **11.2**

A firm that delivers Q units of water to households has a total cost of $C(Q) = mQ + F$. If any entrant would have the same cost, does this market have a natural monopoly?

Answer

Determine whether costs rise if two firms produce a given quantity: Let q_1 be the output of Firm 1 and q_2 be the output of Firm 2. The combined cost of these two firms producing $Q = q_1 + q_2$ is

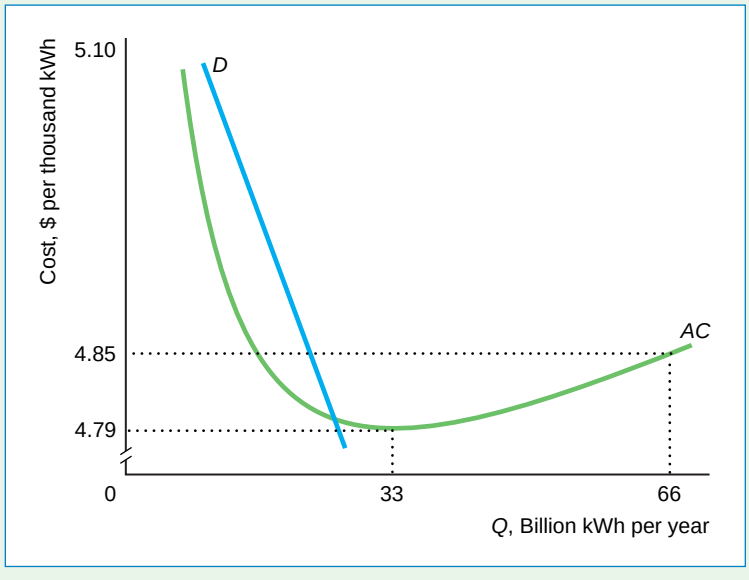
$$C(q_1) + C(q_2) = (mq_1 + F) + (mq_2 + F) = m(q_1 + q_2) + 2F = mQ + 2F.$$

If a single firm produces Q, its cost is $C(Q) = mQ + F$. Thus the cost of producing any given Q is greater with two firms than with one firm, so this market has a natural monopoly.

Application

ELECTRIC POWER UTILITIES

According to the estimates of Christensen and Greene (1976), the average cost curve for U.S. electric-power-producing firms in 1970 was U-shaped, reaching its minimum at 33 billion kilowatt-hours (kWh) per year (see graph). Thus



whether an electric power utility was a natural monopoly depended on the demand it faced.

For example, if the demand curve for an electric utility was *D* on the graph, the quantity demanded was less than 33 billion kWh per year at any price, so the electric utility operated in the strictly declining section of its average cost curve and was a natural monopoly. In 1970, most electric companies were operating in regions of substantial economies of scale. Newport Electric produced only 0.5 billion kWh per year, and Iowa Southern Utilities produced 1.3 billion kWh per year.

A few of these firms operated in the upward-sloping section of the average cost curve and were not natural monopolies. The largest electric utility in 1970, Southern, produced 54 billion kWh per year. It was not a natural monopoly because two firms could produce that quantity at 3¢ less per thousand kWh than a single firm could. As the graph shows, two firms producing 33 billion kWh each have an average cost of $4.79 per thousand kWh, while one firm producing 66 billion kWh has an average cost of $4.85, or 6¢ more per thousand kWh.

11.6 GOVERNMENT ACTIONS THAT CREATE MONOPOLIES

Governments create many monopolies. Sometimes governments own and manage monopolies. In the United States, as in most countries, the postal service is a government monopoly. Indeed, the U.S. Constitution explicitly grants the government the right to establish a postal service. Many local governments own and operate public utility monopolies that provide garbage collection, electricity, water, gas, phone services, and other utilities.

Frequently, however, governments create monopolies by preventing competing firms from entering a market. For example, when a government grants a patent, it limits entry and allows the patent-holding firm to earn a monopoly profit from an invention—a reward for developing the new product.

Barriers to Entry

By preventing other firms from entering a market, governments create monopolies. Typically, governments create monopolies in one of three ways: by making it difficult for new firms to obtain a license to operate, by granting a firm the rights to be a monopoly, or by auctioning the rights to be a monopoly.

Frequently, firms need government licenses to operate. If governments make it difficult for new firms to obtain licenses, the first firm may maintain its monopoly. Until recently, many U.S. cities required that new hospitals or other inpatient facilities demonstrate the need for a new facility to obtain a certificate of need, which allowed them to enter the market.

Government grants of monopoly rights have been common for public utilities. Instead of running a public utility itself, a government gives a private company the monopoly rights to operate the utility. As discussed in the application on airport monopoly concessions, a government may capture some of the monopoly profits by

charging a high rent to the monopoly. Alternatively, government officials may capture the rents for monopoly rights by means of bribes.

Governments around the world have privatized many state-owned monopolies in the past several decades. By selling its monopolies to private firms, a government can capture the value of future monopoly earnings today.[19] However, for political or other reasons, governments frequently sell at a lower price that does not capture all future profits.

Application

ICELAND'S GOVERNMENT CREATES GENETIC MONOPOLY

Starting in 874, Viking crews from western Norway kidnapped young Celtic women from Ireland and sailed off with them to what we know now as Iceland. More than 11 centuries later, the descendants of these 10,000 to 15,000 pirates and their roughly five-times-as-many slave wives form an unusually isolated population with a relatively homogeneous gene pool. Iceland has tissue samples dating back to the 1940s and has maintained meticulous records on every citizen since 1915. In addition, careful genealogic records have been kept that allow researchers to trace disease genes back more than 10 generations.

Dr. Kari Stefansson, a native Icelander and former Harvard Neuropathologist, believed that the unique genetic dataset of the 286,000 current Icelanders (and many of their forebears) could be used to pinpoint the genetics of some of the most serious common diseases. Toward that end, he formed a firm, deCODE Genetics. In 1998, the firm acquired 12 years of monopoly rights to the genetic, medical, and genealogical records of Iceland for about $200 million. In addition, the firm agreed to provide Icelanders with free drugs and diagnostic tools stemming from their research. Since then, the firm has collected voluntary blood samples from tens of thousands of people to augment its databases. By 2002, deCODE had announced findings for a number of diseases. With revenues of $13.4 million, it hopes for much greater returns in the near future.

Patents

If a firm cannot prevent imitation by keeping its discovery secret, it may obtain government protection to prevent other firms from duplicating its discovery and entering the market. Virtually all countries provide such protection through a **patent**: an exclusive right granted to the inventor to sell a new and useful product, process, substance, or design for a fixed period of time. A patent grants an inventor the right to be the monopoly provider of the good for a number of years.

Patent Length. The length of a patent varies across countries. The U.S. Constitution explicitly gives the government the right to grant authors and inventors exclusive rights to their writings (copyrights) and to their discoveries (patents) for limited peri-

[19]See **www.aw.com/perloff**, Chapter 11, "Government Sales of Monopolies."

ods of time. Traditionally, U.S. patents lasted *17 years* from the date they were *granted*, but the United States agreed in 1995 to change its patent law as part of a GATT agreement. Now U.S. patents last for *20 years* after the date the inventor *files* for patent protection. The length of protection is likely to be shorter under the new rules, because it frequently takes more than three years after filing to obtain final approval of a patent.

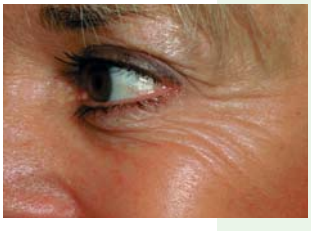
Many European countries granted patent protection for very short periods of time, but these patents could be renewed upon the payment of a fee. The renewal fee was due in two years in France, three in Germany, and five in the United Kingdom. A patent could be renewed until it was 16 years old in Britain, 18 in Germany, and 20 in France.

Patents Stimulate Research. A firm with a patent monopoly sets a high price that results in deadweight loss. Why, then, do governments grant patent monopolies? The main reason is that inventive activity would fall if there were no patent monopolies or other incentives to inventors. The costs of developing a new drug or new computer chip are often hundreds of millions or even billions of dollars. If anyone could copy a new drug or chip and compete with the inventor, few individuals or firms would undertake costly research. Thus the government is explicitly trading off the long-run benefits of additional inventions against the shorter-term harms of monopoly pricing during the period of patent protection.

Application

BOTOX PATENT MONOPOLY

Ophthalmologist Dr. Alan Scott, turned the deadly poison botulinum toxin into a miracle drug to treat two conditions: strabismus which affects about 4% of children; and blepharospasm, an uncontrollable closure of the eyes. Blepharospasm left about 25,000 Americans functionally blind before Scott's discovery. His patented drug, Botox, is sold by Allergan, Inc.



Dr. Scott has been amused to see several of the unintended beneficiaries of his research at the Academy Awards. Even before it was explicitly approved for cosmetic use, many doctors were injecting Botox into the facial muscles of actors, models, and others to smooth out their wrinkles. (The drug paralyzes the muscles, so those injected with it also lose the ability to frown—and, some would say, to act.) Ideally for Allergan, the treatment is only temporary, lasting up to 120 days, so repeated injections are necessary. Allergan had expected to sell $400 million worth of Botox in 2002. However, in April of that year, the Federal Food and Drug Administration approved of the use of Botox for cosmetic purposes, a ruling that allows the company to advertise the drug widely.

The firm expects Botox eventually to earn a $1 billion a year (becoming another Viagra). Currently, Allergan has a near-monopoly in the treatment for wrinkles, although plastic surgery, collagen injections, and Myobloc (made by Elan, an Irish drug manufacturer) provide limited competition.

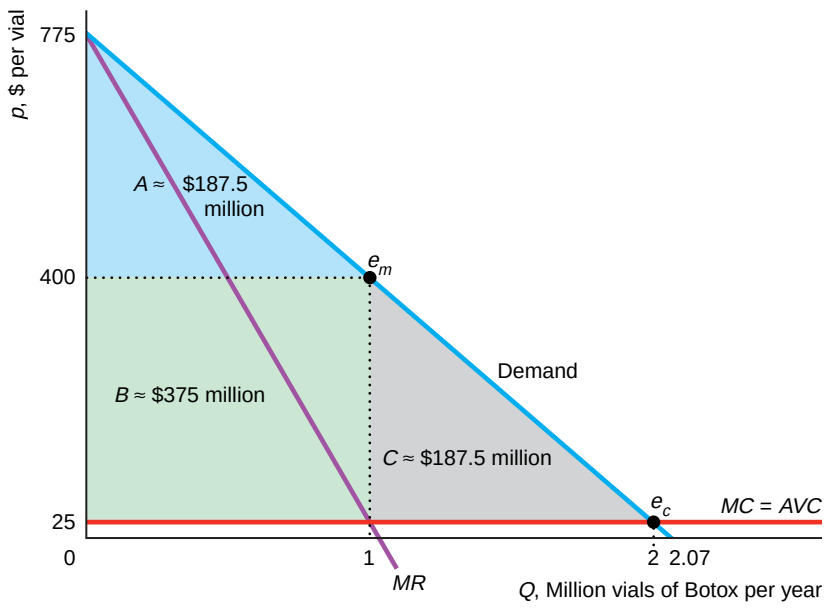
Dr. Scott says that he can produce a vial of Botox in his lab for about $25. Allergan then sells the potion to doctors for about $400. Assuming that the firm is setting its price to maximize its short-run profit, we can rearrange Equation 11.9 to determine the elasticity of demand for Botox:

$$e = -\frac{p}{p - MC} = -\frac{400}{400 - 25} \approx -1.067.$$

Thus the demand that Allergan faces is only slightly elastic: A 1% increase in price causes quantity to fall by only a little more than 1%.

If we assume that the demand curve is linear and that the elasticity of demand is –1.067 at the 2002 monopoly optimum, e_m, (one million vials sold at $400 each, producing revenue of $400 million), then Allergan's inverse demand function is

$$p = 775 - 375Q.$$



This demand curve (see graph) has a slope of –375 and hits the price axis at $775 and the quantity axis at about 2.07 million vials per year. The corresponding marginal revenue curve,

$$MR = 775 - 750Q,$$

strikes the price axis at $775 and has twice the slope, –750, as the demand curve.

The intersection of the marginal revenue and marginal cost curves,

$$MR = 775 - 750Q = 25 = MC,$$

determines the monopoly equilibrium at the profit-maximizing quantity of 1 million vials per year and a price of $400 per vial.

Were the company to sell Botox at a price equal to its marginal cost of $25 (as a competitive industry would), consumer surplus would equal areas $A + B + C = \$750$ million per year. At the higher monopoly price of $400, the consumer surplus is $A = \$187.5$ million. Compared to the competitive solution, e_c, buyers lose consumer surplus of $B + C = \$562.5$ million per year. Part of this loss, $B = \$375$ million per year, is transferred from consumers to Allergan. The rest, $C = \$187.5$ million per year, is the deadweight loss from monopoly pricing. Allergan's profit is its producer surplus, B, minus its fixed costs.

Alternatives to Patents. Instead of using patents to spur research, the government could give research grants or offer prizes. Rather than trying these alternative approaches, Congress has modified the patent system. In the 1960s and 1970s, the effective life of a patent on a drug shrank because of the additional time it took to get FDA approval to sell the drug. By 1978, the average drug had patent protection for fewer than 10 years. The Drug Price Competition and Patent Term Restoration Act of 1984 restored up to three years of the part of the patent life that was lost while the firm demonstrated efficacy and safety to the FDA. At the same time, the act made it easier for generic products to enter at the end of the patent period. Thus the law aimed both to encourage the development of new drugs by increasing the reward—the monopoly period—and to stimulate price competition at the end of the period.

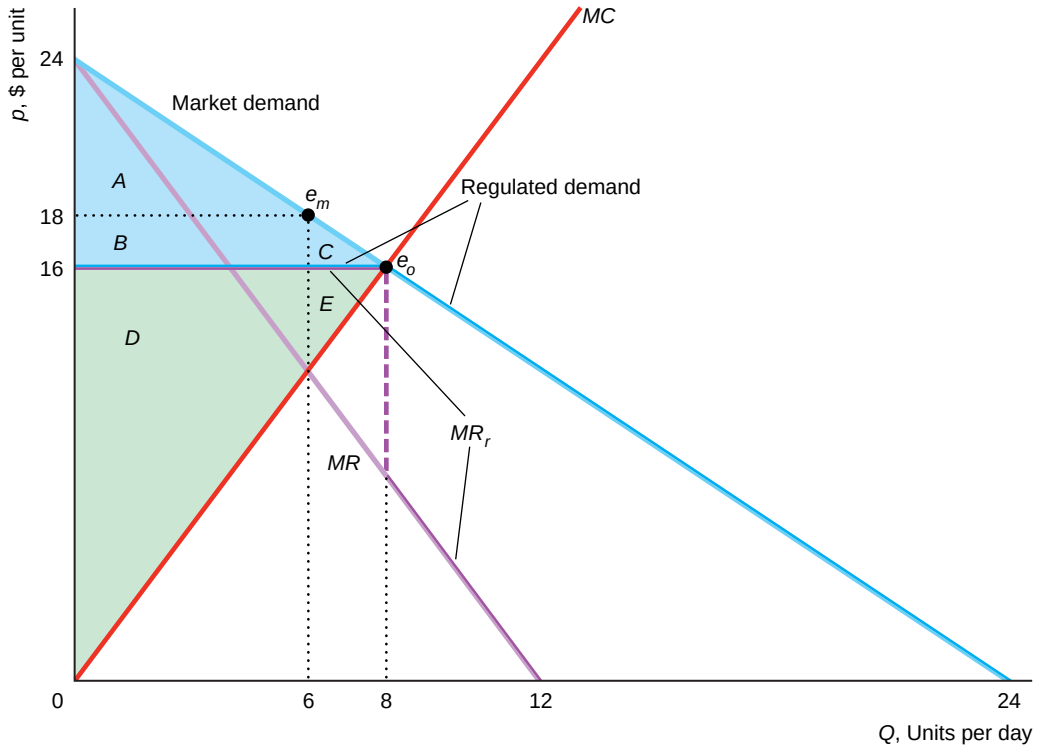
11.7 GOVERNMENT ACTIONS THAT REDUCE MARKET POWER

Some governments act to reduce or eliminate monopolies' market power. Most Western countries have laws forbidding a firm from driving other firms out of the market so as to monopolize it. Many governments either regulate monopolies—especially those that the government has created—or destroy monopolies by breaking them up into smaller, independent firms or encouraging other firms to enter the market.

Regulating Monopolies

Governments limit monopolies' market power in a number of ways. Most utilities, for example, are subject to direct regulation. One method governments use to limit the harms of monopoly is to place a ceiling on the price that a monopoly charges.

Optimal Price Regulation. In some markets, the government can eliminate the deadweight loss of monopoly by requiring that a monopoly charge no more than the competitive price. We use our earlier linear example to illustrate this type of regulation in Figure 11.8.



	Monopoly Without Regulation	Monopoly with Optimal Regulation	Change
Consumer Surplus, *CS*	*A*	*A* + *B* + *C*	*B* + *C* = Δ*CS*
Producer Surplus, *PS*	*B* + *D*	*D* + *E*	*E* − *B* = Δ*PS*
Welfare, *W* = *CS* + *PS*	*A* + *B* + *D*	*A* + *B* + *C* + *D* + *E*	*C* + *E* = Δ*W*
Deadweight Loss, *DWL*	−*C* − *E*	0	*C* + *E* = Δ*DWL*

Figure 11.8 Optimal Price Regulation. If the government sets a price ceiling at $16, where the monopoly's marginal cost curve hits the demand curve, the new demand curve the monopoly faces has a kink at 8 units, and the corresponding marginal revenue curve, MR_r, "jumps" at that quantity. The regulated monopoly sets its output where $MR_r = MC$, selling the same quantity, 8 units, at the same price, $16, as a competitive industry would. The regulation eliminates the monopoly deadweight loss, $C + E$. Consumer surplus, $A + B + C$, and producer surplus, $D + E$, are the same as under competition.

If the government doesn't regulate the profit-maximizing monopoly, the monopoly optimum is e_m, at which 6 units are sold at the monopoly price of \$18. Suppose that the government sets a ceiling price of \$16, the price at which the marginal cost curve intersects the market demand curve. Because the monopoly cannot charge more than \$16 per unit, the monopoly's regulated demand curve is horizontal at \$16 (up to 8 units) and is the same as the market demand curve at lower prices. The marginal revenue, MR_r, corresponding to the regulated demand curve is horizontal where the regulated demand curve is horizontal (up to 8 units) and equals the marginal revenue curve, MR, corresponding to the market demand curve at larger quantities.

The regulated monopoly sets its output at 8 units, where MR_r equals its marginal cost, MC, and charges the maximum permitted price of \$16. The regulated firm still makes a profit, because its average cost is less than \$16 at 8 units. The optimally regulated monopoly optimum, e_o, is the same as the competitive equilibrium, where marginal cost (supply) equals the market demand curve.[20] Thus setting a price ceiling where the MC curve and market demand curve intersect eliminates the deadweight loss of monopoly.

How do we know that this regulation is optimal? The answer is that this regulated outcome is the same as would occur if this market were competitive, where welfare is maximized (Chapter 9). As the table accompanying Figure 11.8 shows, the deadweight loss of monopoly, $C + E$, is eliminated by this optimal regulation.

Nonoptimal Price Regulation. Welfare is reduced if the government does not set the price optimally. Suppose that the government sets the regulated price below the optimal level, which is \$16 in our example. If it sets the price below the firm's minimum average cost, the firm shuts down. If that happens, the deadweight loss equals the sum of the consumer plus producer surplus under optimal regulation, $A + B + C + D + E$.

If the government sets the price ceiling below the optimally regulated price but high enough that the firm does not shut down, consumers who are lucky enough to buy the good are better off because they can buy goods at a lower price than with optimal regulation. Some customers, however, are frustrated because the monopoly will not sell them the good, as we show next. There is a deadweight loss because less output is sold than with optimal regulation. (Question 10 at the end of the chapter asks you to determine the effects of a regulated price that is above the optimal level.)

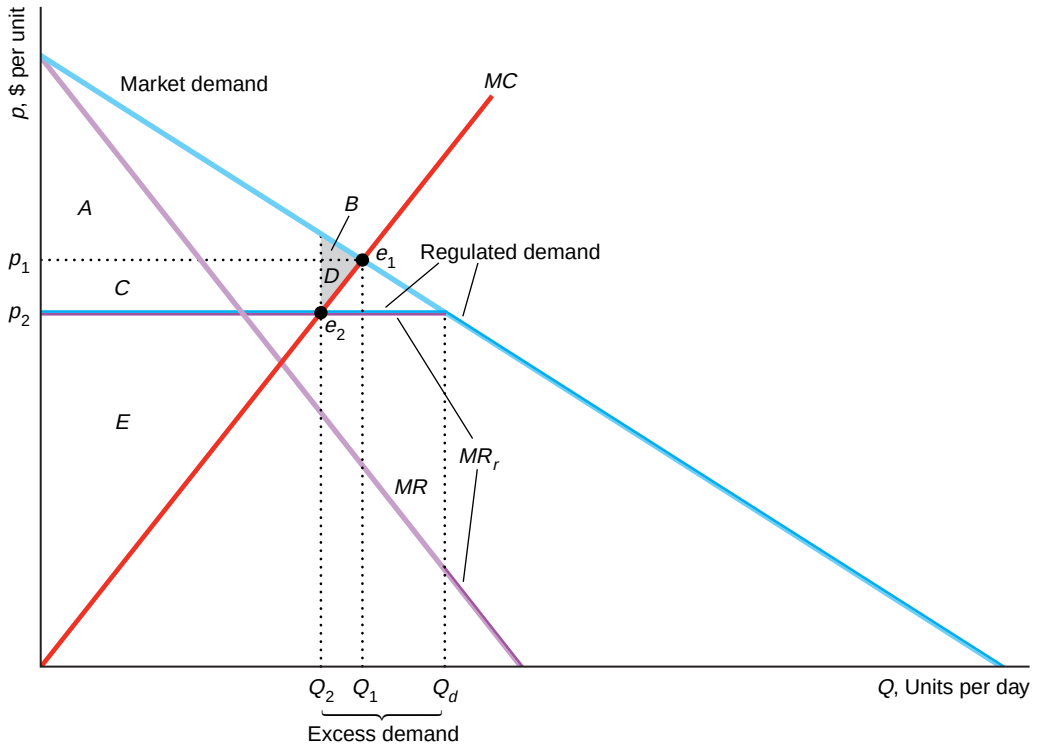
Solved Problem 11.3

Suppose that the government sets a price, p_2, that is below the socially optimal level, p_1, but above the monopoly's minimum average cost. How do the price, the quantity sold, the quantity demanded, and welfare under this regulation compare to those under optimal regulation?

Answer

1. *Describe the optimally regulated outcome*: With optimal regulation, e_1, the price is set at p_1, where the market demand curve intersects the

[20]The monopoly produces at e_o only if the regulated price is greater than its average variable cost. Here the regulated price, \$16, exceeds the average variable cost at 8 units of \$8. Indeed, the firm makes a profit because the average cost at 8 units is \$9.50.



	Monopoly with Optimal Regulation	Monopoly with a Low Regulated Price	Change
Consumer Surplus, *CS*	*A* + *B*	*A* + *C*	*C* − *B* = Δ*CS*
Producer Surplus, *PS*	*C* + *D* + *E*	*E*	−*C* − *D* = Δ*PS*
Welfare, *W* = *CS* + *PS*	*A* + *B* + *C* + *D* + *E*	*A* + *C* + *E*	−*B* − *D* = Δ*W* = *DWL*

monopoly's marginal cost curve on the accompanying graph. The optimally regulated monopoly sells Q_1 units.

2. *Describe the outcome when the government regulates the price at p_2*: Where the market demand is above p_2, the regulated demand curve for the monopoly is horizontal at p_2 (up to Q_d). The corresponding marginal revenue curve, MR_r, is horizontal where the regulated demand curve is horizontal and equals the marginal revenue curve corresponding to the market demand curve, *MR*, where the regulated demand curve is downward sloping. The monopoly maximizes its profit by selling Q_2 units at p_2. The new regulated monopoly optimum is e_2, where MR_r intersects *MC*. The firm does not shut down when regulated as long as its average variable cost at Q_2 is less than p_2.

3. *Compare the outcomes*: The quantity that the monopoly sells falls from Q_1 to Q_2 when the government lowers its price ceiling from p_1 to p_2. At that low price, consumers want to buy Q_d, so there is excess demand equal to $Q_d - Q_2$. Compared to optimal regulation, welfare is lower by at least $B + D$.[21]

Problems in Regulating. Governments face several problems in regulating monopolies. First, because they do not know the actual demand and marginal cost curves, governments may set the price at the wrong level. Second, many governments use regulations that are less efficient than price regulation. Third, regulated firms may bribe or otherwise influence government regulators to help the firms rather than society as a whole.

Because of limited information about the demand and marginal cost curves, governments may set a price ceiling above or below the competitive level. Moreover, a regulatory agency may have to set the price higher than is optimal because it cannot offer a subsidy.

If the regulatory agency were to set the price equal to a natural monopoly's marginal cost, the price would be below the firm's average cost. The monopoly would threaten to shut down unless the regulatory agency were to subsidize it or raise the price.

To illustrate this problem, we calculate how setting the price too low would affect the electric power monopoly in Kyushu, Japan.[22] In the absence of regulation and in light of the curves in Figure 11.9, this firm maximizes its profit by operating where its marginal cost equals its marginal revenue, where it sells 23 billion kWh at ¥30.3 per hundred kWh and makes a profit equal to area *A*.

This firm would lose money if it faced a price ceiling of ¥19.5, where the demand curve intersects the marginal cost curve at 34 billion kWh. At that quantity, its average cost of ¥21.9 is greater than the price ceiling, and the firm loses an amount equal to area *B*. Thus if the government wants the firm to charge a price equal to marginal cost, it would have to subsidize the firm by at least *B* to keep it from shutting down.

Typically, it is politically infeasible for a government regulatory agency to subsidize a firm. Instead, the agency might set the price at ¥22.3, at which the demand curve intersects the average cost curve and the monopoly breaks even. There is still a deadweight loss because that price is above marginal cost, but the deadweight loss is smaller than if the monopoly were unregulated.

---

[21]The welfare loss is greater if unlucky consumers waste time trying to buy the good unsuccessfully or if goods are not allocated optimally among consumers. A consumer who values the good at only p_2 may be lucky enough to buy it, while a consumer who values the good at p_1 or more may not be able to obtain it.

[22]The cost curves in this example are based on the estimated short-run average cost curve in Nemoto, Nakanishi, and Madono (1993). To create an example of a possible demand curve, we assume that the demand is linear and that the electricity demand of Japanese consumers at the observed output is the same as that of American consumers (Maddock, Castano, and Vella, 1992).

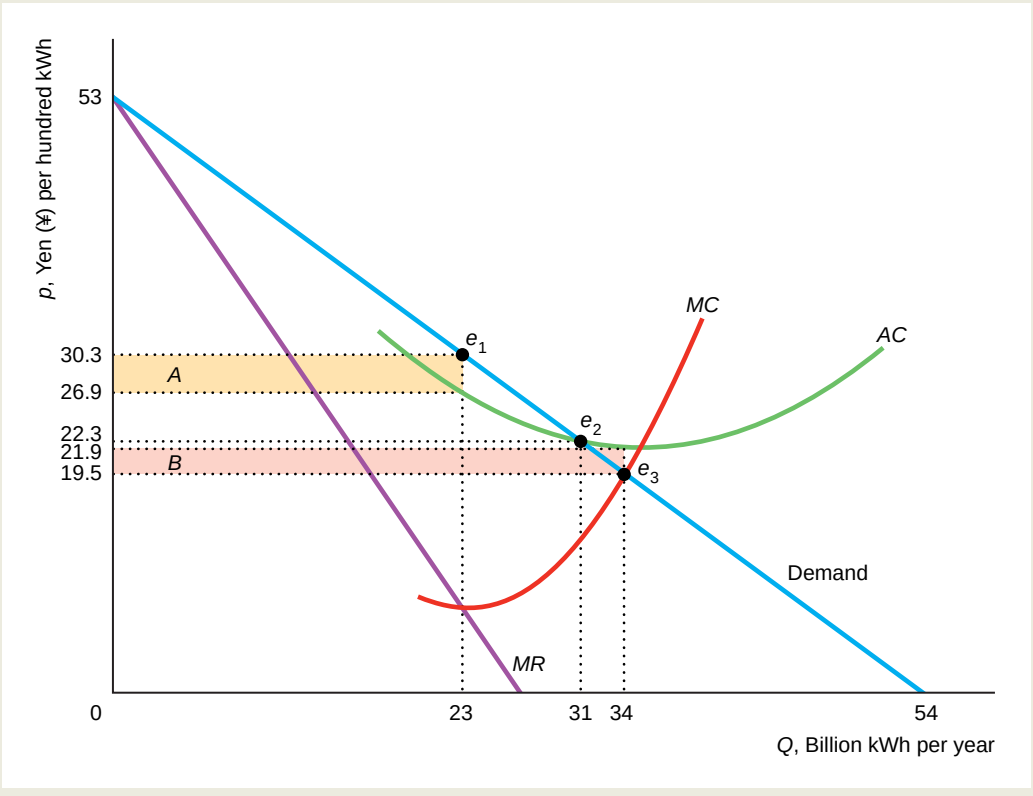


Figure 11.9 Regulating an Electric Utility. If the electric utility is an unregulated, profit-maximizing monopoly, e_1, it sets its output at 23 billion kWh and charges ¥30.3 per hundred kWh and makes a profit of area *A*. The government may regulate price so that the utility breaks even, e_2. Alternatively, the government may regulate the utility to behave like a price taker, e_3. If so, the government must subsidize the utility by area *B* to keep it from shutting down.

Unfortunately, regulation is often not effective when regulators are *captured*: influenced by the firms they regulate. Typically, this influence is more subtle than an outright bribe. Many American regulators have worked in the industry before they became regulators and hence are sympathetic to those firms. Many regulators hope to obtain good jobs in the industry eventually, so they don't want to offend potential employers. Other regulators, relying on industry experts for their information, may be misled or at least heavily influenced by the industry. For example, the California Public Utilities Commission urged telephone and cable companies to negotiate among themselves as to how they wanted to open local phone markets to competition by 1997. Arguing that these influences are inherent, some economists contend that price and other types of regulation are unlikely to result in efficiency.

Increasing Competition

Encouraging competition is an alternative to regulation as a means of reducing the harms of monopoly. When a government has created a monopoly by preventing entry, it can quickly reduce the monopoly's market power by allowing other firms

to enter. As new firms enter the market, the former monopoly must lower its price to compete, so welfare rises. Many governments are actively encouraging entry into telephone, electricity, and other utility markets that were formerly monopolized.

Similarly, a government may end a ban on imports so that a domestic monopoly faces competition from foreign firms. If costs for the domestic firm are the same as costs for the foreign firms and there are many foreign firms, the former monopoly becomes just one of many competitive firms. As the market becomes competitive, consumers pay the competitive price, and the deadweight loss of monopoly is eliminated.

Governments around the world are increasing competition in formerly monopolized markets. For example, many U.S. and European governments are forcing former telephone and energy monopolies to compete. See **www.aw.com/perloff**, "Ending the Monopoly in Telephone Service" and "Deregulating Energy."

Dominant Firm and Competitive Fringe

Sometimes when a monopoly ends, the former monopoly maintains a cost advantage over later entrants. Suppose that the government eliminates an import restriction and a number of foreign firms enter the market. These firms have higher costs than the domestic firm because of shipping costs. Each foreign firm is such a small part of the market that it acts as a price-taking competitive firm.

The former monopoly becomes a **dominant firm**: a price-setting firm that competes with price-taking firms. Small price-taking firms that compete with a dominant firm are called the **competitive fringe** (or *fringe*).

The dominant firm maximizes its profit given its cost curves and the demand curve it faces. Before the entry of the fringe, the monopoly faces the market demand curve, D in Figure 11.10. The fringe takes some of the market demand from the former monopoly. As a result, the demand curve the dominant firm faces after the fringe enters is a **residual demand curve**: the market demand that is not met by other sellers (the competitive fringe) at any given price (see Chapter 8).

The residual demand curve for the dominant firm is the horizontal difference between the market demand curve and the fringe supply curve: At any given price, p, the residual demand for the dominant firm, D^r, is

$$D^r(p) = D(p) - S^f(p),$$

where S^f is the supply curve of the fringe. As Figure 11.10 shows, the fringe supplies nothing at p_1 or any lower price, so the residual demand is the same as the market demand. At p^*, the residual demand is q_d^*, which equals the market demand, Q^*, minus the fringe supply, Q_f^*. At p_2, the fringe supplies as much as the market demands (S^f intersects D at p_2), so the residual demand is zero.

The dominant firm's marginal revenue curve is MR^r, which corresponds to the residual demand curve, D^r. The dominant firm maximizes its profit at point d by setting a price of p^*, where it sells q_d^* units—the quantity where MR^r intersects its marginal cost curve, MC^d. The fringe sells Q_f^* for p^*, at point f. At the market equilibrium, point e, the total amount that the dominant firm and the fringe sell, $q_d^* + Q_p^*$, equals the quantity the market demands at that price, Q^*, so neither consumers nor producers want to change their behavior.

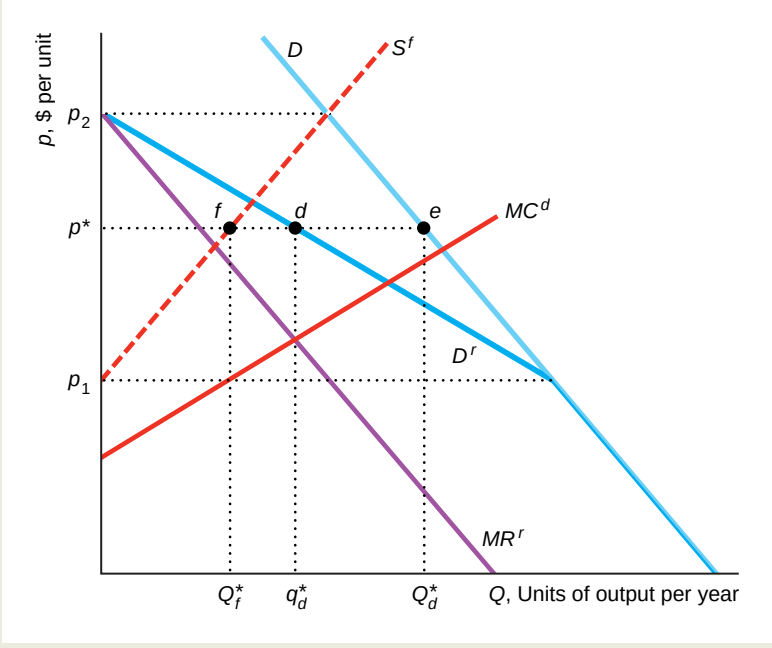


Figure 11.10 Dominant Firm–Competitive Fringe Equilibrium. The residual demand for the dominant firm, D^r, is the horizontal difference between the market demand curve, D, and the supply curve of the fringe firms, S^f. The dominant firm maximizes its profit at d by setting a price of p^* and selling q_d units where its residual demand curve, MR^r, intersects its marginal cost curve, MC^d. The fringe operates at point f, and the market equilibrium is point e.

Because of the upward-sloping supply curve of the fringe, the dominant firm's residual demand curve, D^r, lies below and is flatter than the market demand curve, D, that the monopoly faced. As a result, the dominant firm faces a more elastic demand than the monopoly did, which causes the dominant firm to set a lower price. At this lower price, consumers demand more, and the dominant firm and the fringe produce more collectively than the monopoly did alone. Thus the fringe erodes but does not eliminate the dominant firm's market power. Consumers benefit from the entry of the fringe, and some, but not all, of the deadweight loss under monopoly is eliminated.

Summary

1. **Monopoly profit maximization:** Like any firm, a monopoly—a single seller—maximizes its profit by setting its output so that its marginal revenue equals its marginal cost. The monopoly makes a positive profit if its average cost is less than the price at the profit-maximizing output.
2. **Market power:** Market power is the ability of a firm to charge a price above marginal cost and earn a positive profit. The more elastic the demand the monopoly faces at the quantity at which it maximizes its profit, the closer its price to its marginal cost and the closer the Lerner

Index or price markup, $(p - MC)/p$, to zero, the competitive level.

3. **Effects of a shift of the demand curve:** Because a monopoly does not have a supply curve, the effect of a shift in demand on a monopoly's output depends on the shapes of both its marginal cost curve and its demand curve. As a monopoly's demand curve shifts, price and output may change in the same direction or different directions.

4. **Welfare effects of monopoly:** Because a monopoly's price is above its marginal cost, too little output is produced, and society suffers a deadweight loss. The monopoly makes higher profit than it would if it acted as a price taker. Consumers are worse off, buying less output at a higher price.

5. **Cost advantages that create monopolies:** A firm may be a monopoly if it controls a key input, has superior knowledge about producing or distributing a good, or has substantial economies of scale. In markets with substantial economies of scale, the single seller is called a natural monopoly because total production costs would rise if more than one firm produced.

6. **Government actions that create monopolies:** Governments may establish government-owned and -operated monopolies. They may also create private monopolies by establishing barriers to entry that prevent other firms from competing. Nations grant patents, which give inventors monopoly rights for a limited period of time.

7. **Government actions that reduce market power:** A government can eliminate the welfare harm of a monopoly by forcing the firm to set its price at the competitive level. If the government sets the price at a different level or otherwise regulates nonoptimally, welfare at the regulated monopoly optimum is lower than in the competitive equilibrium. A government can eliminate or reduce the harms of monopoly by allowing or facilitating entry.

Questions

1. Show that after a shift in the demand curve, a monopoly's price may remain constant but its output may rise.
2. What is the effect of a franchise (lump-sum) tax on a monopoly? (*Hint*: Consider the possibility that the firm may shut down.)
3. What is the effect of a profit tax on a monopoly? Assume the government takes γ fraction of the before-tax economic profit, π, and the monopoly maximizes the after-tax profit, $(1 - \gamma)\pi$.
4. When is a monopoly unlikely to be profitable? (*Hint*: Discuss the relationship between market demand and average cost.)
5. A monopoly has a constant marginal cost of production of \$1 per unit and a fixed cost of \$10. Draw the firm's *MC*, *AVC*, and *AC* curves. Add a downward-sloping demand curve, and show the profit-maximizing quantity and price. Indicate the profit as an area on your diagram. Show the deadweight loss.
6. Can a firm be a natural monopoly if it has a U-shaped average cost curve? Why or why not?
7. Can a firm operating in the upward sloping portion of its average cost curve be a natural monopoly? Explain.
8. *Review* (Chapter 8): Show why a monopoly may operate in the upward- or downward-sloping section of its long-run average cost curve but a competitive firm will operate only in the upward-sloping section.
9. When will a monopoly set its price equal to its marginal cost?
10. Describe the effects on output and welfare if the government regulates a monopoly so that it may not charge a price above $\bar{p}$, which lies between the unregulated monopoly price and the optimally regulated price (determined by the intersection of the firm's marginal cost and the market demand curve).

★11. *Review* (Chapter 10): Suppose that many similar price-taking consumers (like Denise in Chapter 10) have a single good (candy bars) and that Jane has a monopoly in wood. Thus Jane can set prices. Assume that no production is possible. Using an Edgeworth box, illustrate the monopoly optimum

and show that it does not lie on the contract curve (isn't Pareto efficient).

12. A monopoly drug company produces a lifesaving medicine at a constant cost of $10 per dose. The demand for this medicine is perfectly inelastic at prices less than or equal to the $100 (per day) income of the 100 patients who need to take this drug daily. At a higher price, nothing is bought. Show the equilibrium price and quantity and the consumer and producer surplus in a graph. Now the government imposes a price ceiling of $30. Show how the equilibrium, consumer surplus, and producer surplus change. What is the deadweight loss, if any, from this price control?

13. The price of wholesale milk dropped by 30.3% in 1999 as the Pennsylvania Milk Marketing Board lowered the regulated price. The price to consumers fell by substantially less than 30.3% in Philadelphia. Why? (*Hint*: Show that a monopoly will not necessarily lower its price by the same percentage as its constant marginal cost drops.)

14. Today, drug companies spend large sums to determine additional uses for their existing drugs. For example, GlaxoWellcome PLC, a pharmaceutical giant, learned that its drug bupropion hydrochloride is more effective than the nicotine patch for people trying to quit smoking. That drug is now sold as Zyban, but it was introduced in 1997 as an antidepressant, Wellbutrin. Projected 1999 sales were $250 million for Zyban and $590 million for Wellbutrin. Using a graph, show the demand curves for Wellbutrin and Zyban and the aggregate demand for this drug, buproprion hydrochloride. On the graph, indicate the quantity of pills sold for each use and total use at the current price. Why does Glaxo, the monopoly producer, set the same price, $1.16 a pill, for both drugs?

15. Suppose that the competitive fringe's supply curve is horizontal in the long run. Show and describe the resulting dominant firm–competitive fringe equilibrium.

16. Show that the deadweight loss is higher in a monopoly optimum than in a dominant firm–competitive fringe equilibrium.

Problems

★17. Show mathematically that a monopoly may raise the price to consumers by more than the specific tax imposed on it. (*Hint*: One approach is to consider a monopoly facing a constant-elasticity demand curve and a constant marginal cost, m.)

18. The inverse demand curve a monopoly faces is
$$p = 100 - Q.$$
The firm's cost curve is $C(Q) = 10 + 5Q$. What is the profit-maximizing solution?

19. How does your answer to Problem 18 change if $C(Q) = 100 + 5Q$?

20. The inverse demand curve a monopoly faces is
$$p = 10Q^{-\frac{1}{2}}.$$
The firm's cost curve is $C(Q) = 5Q$. What is the profit-maximizing solution?

21. If the inverse demand function facing a monopoly is $P(Q)$ and its cost function is $C(Q)$, show the effect of a specific tax, τ, on its profit-maximizing output. How does imposing τ affect its profit?

22. In the Botox application, consumer surplus, triangle A, equals the deadweight loss, triangle C. Show that this equality is a result of the linear demand and constant marginal cost assumptions.

★23. *Review* (Chapters 6 and 7): A monopoly's production function is Cobb-Douglas: $Q = L^{\frac{1}{2}}K^{\frac{1}{2}}$, where L is labor and K is capital. As a result, the marginal product functions are $MP_L = \frac{1}{2}K^{\frac{1}{2}}/L^{\frac{1}{2}}$ and $MP_K = \frac{1}{2}L^{\frac{1}{2}}/K^{\frac{1}{2}}$. The demand function is $p = 100 - Q$. The wage, w, is $1 per hour, and the rental cost of capital, r, is $4.
   a. What is the equation of the (long-run) expansion path? Illustrate in a graph.
   b. Derive the long-run total cost curve equation as a function of q.
   c. What quantity maximizes this firm's profit?
   d. Find the optimal input combination that produces the profit-maximizing quantity. Illustrate with a graph.