Part VII Networks and Auctions

In this final part of the text, we explore topics that do not fit easily within our earlier classifications. The first of these is network externalities. For many goods, such as telephones, the value of the product to any one consumer rises as additional consumers buy it. Such network effects greatly alter both the nature of industry competition and the characteristics of the market outcome. Often, network externalities and the complementarities that underlie them give rise to multiple equilibria with no guarantee that the actual equilibrium chosen will be the best of these. Further, because network externalities act much like scale economies except that they work on the demand side, they create strong incentives for firms to operate on a large scale with the result that the market will inevitably be dominated by those few firms that survive. In turn, because not just some profit but a firm's very survival may be at stake, competition in industries with important network effects can be incredibly fierce. We explore these issues in some detail. We also include an empirical study that tries to identify network characteristics in a market for computer software.

In Chapter 25, we switch gears somewhat and turn to the topic of auctions. Auctions have been around for a very long time and, partly because of this historical pedigree, have often been viewed as the paradigm of competitive markets even though few markets might actually be described as auctions. In recent years, however, auctions have re-emerged as a common market arrangement. Financial markets, of course, have long relied on auctions. However, partly because of the privatization movement, governments also have increasingly employed an auction mechanism to sell rail lines, oil facilities and lease tracts, mobile phone licenses, and a host of other assets. Similarly, the rise of e-Bay and other commercial sites offers further evidence of the increased popularity of the auction process.

Our analysis of the auction phenomenon begins with a review of Vickery's (1961) classic piece leading to the Revenue Equivalence theorem which says that, under certain rather broad conditions, the final auction price is independent of the auction design. We then examine various ways in which this outcome might break down and the auction lead to an inefficient result in which the prize does not go to the buyer who valued it most highly. The interesting feature of such failures is that often they stem from a common source—lack of competition due to either small numbers, or collusive bidding, or both. We then consider how auctions might be alternatively designed to surmount these problems, demonstrating that industrial organization theory has practical insights, as well.

24

Network Issues

Microsoft Corporation—perhaps no single firm is more closely associated with the telecommunications revolution that has swept through both businesses and households in the last part of the twentieth century than this giant of the software industry. Nor perhaps does any other company better capture the popular view of the opportunities for fame and fortune that the "new economy" presents. Starting out as a simple provider of programming language, Microsoft became the supplier of over 90 percent of the operating systems for personal computers. It holds equally commanding shares in many markets for peripheral programs, such as that for word-processing (Word) and electronic spreadsheets (Excel). From a small, two-person enterprise with essentially zero net worth in 1975, the firm has grown to a firm of over 30,000 employees with a net worth of over $44 billion in 2007.

Of course, Microsoft is not the only success story of the digital economy age. Among the other Cinderella-firms of recent years is e-Bay, the online auction company. A small startup firm created by Pierre Omidyar in 1995, e-Bay now has over ten million registered users and conducts over one million person-to-person auctions each day. These transactions initially involved only low-price collectibles, from Star War action figures to Japanese maple trees. However, the site now brokers trades of many everyday items including toys and games, concert tickets, and even used cars. Prior to the 1990s, direct trade in many items, especially collectibles, had been limited because of the extreme cost of matching a potential buyer with a potential seller. Omidyar was among the first to recognize the enormous potential of the Internet—which makes it easy to disseminate a vast amount of information to a large number of buyers and sellers in a very short time—to solve this problem.

Neither Microsoft nor e-Bay is alone in its respective market. There are other operating system platforms, such as Macintosh or Linux, and other online auction sites. Nevertheless both firms have come to dominate their respective markets. Moreover, each of these markets shares an important feature. One reason that so many people use the Windows operating system is that they expect others will use it as well. The more people that use Windows the more software that will be written for Windows and the more useful therefore Windows will be. Similarly, the more buyers that try to buy on e-Bay, the more sellers will want to sell there which in turn attracts more buyers and so on.

When the value of a product to any one consumer increases as the number of other consumers using the product increases, we say that the market for that product exhibits network externalities or demand-side scale economies. When these effects are important, new strategic considerations come into play. In this chapter, we investigate these issues and the type of market outcomes that are likely when important network effects are present.[1]

24.1 MONOPOLY PROVISION OF A NETWORK SERVICE

An early but insightful analysis of network issues is that provided by Rohlfs (1974). Rohlfs approach is quite straightforward and draws attention to the main issues that arise in network settings. It simplifies the supply side by assuming a monopoly so that the analysis can focus on the central demand-side aspects that give rise to network effects. We present a simplified version of Rohlfs model here.

Assume that the monopolist, say a telecommunications firm, charges an access fee but does not impose a per usage charge. That is, the consumer is charged a single price p for "hooking up" to the network but each individual call is free, perhaps because the marginal cost of a call is zero.[2] We will also assume that there is a maximum size of the market, say one million, reflecting the maximum number of consumers who would ever willingly buy the product even if the access fee were zero. By fixing the total amount of potential customers, we can talk interchangeably about the actual number served and the fraction f of the market that is served. That is, if the maximum size of the market is one million, we can characterize a market outcome in which 100,000 purchase the service either in terms of the total output of 100,000 units or the fraction $f = 0.10$ that is served. For our purposes, it is easier to work with f.

Consumers all agree that the service is more valuable the greater the fraction f of the market that signs up for it. However, even if everyone acquires the service ($f = 1$), consumers would still vary in their valuation or willingness to pay for the service. Specifically, we denote the valuation of the ith consumer when $f = 1$, as v_i. These valuations or v_i's are assumed to be uniformly distributed between 0 and \$100. For example, the one percent of consumers who most value the service (roughly about 10,000 individuals in our case) would willingly pay about \$100 for it if all other consumers also acquire it. However, as the fraction of consumers who sign up declines, so does each consumer's willingness to pay. The easiest way to reflect this assumption is that the ith consumer's valuation of the service for any value of f is given by fv_i. The demand by consumer i for a hook up to the communications service is therefore given by

$$q_i^D = \begin{cases} 0 \text{ if } fv_i < p \\ 1 \text{ if } fv_i \geq p \end{cases} \tag{24.1}$$

Again, it is worth pointing out that the influence of network size works here through f. For consumer i, equation (24.1) says that consumer i's willingness to pay for the service fv_i increases with the fraction of potential buyers f that have bought into the service. It is this interdependence between the willingness to pay and the fraction of the market served that leads to network externalities. In addition, each potential user of the network considers only the value to herself of joining the network. What she does not take into account are the

[1] For a formal but very readable introduction to network externalities, see Economides (1996).
[2] Note that this pricing policy is essentially that of a two-part tariff as described in Chapter 6.

external benefits she creates when she joins the network. By joining she will improve the usefulness of the network to all of the other users since now the network is bigger.

We can use equation (24.1) to calculate the fraction of the market that will sign on to the service at any given price p. As usual, we start by focusing on the marginal consumer denoted by the reservation valuation $\tilde{v}_i$. This is the consumer who is just indifferent between buying into the service network and not buying into it so that $\tilde{v}_i = p/f$. All consumers with a valuation less than $\tilde{v}_i$ will not subscribe to the service. The remainder will subscribe. Since v_i is distributed uniformly between 0 and 100, the fraction of consumers with a valuation below $\tilde{v}_i$ is simply $\tilde{v}_i/100$. Hence, the fraction of consumers f with valuations greater than $\tilde{v}_i$ and who therefore acquire the service is

$$f = 1 - \frac{\tilde{v}_i}{100} = 1 - \frac{p}{100f} \tag{24.2}$$

If we now solve for p we obtain the inverse demand function confronting the monopolist expressed in terms of the fraction f of the maximum potential number of customers who actually buy the service as

$$p = 100f(1 - f) \tag{24.3}$$

This is illustrated in Figure 24.1.

The curve shown in Figure 24.1 is interesting in a number of respects. Note first that for all prices greater than \$25, no equilibrium with a positive value of f exists. If for some reason, the monopolist must charge a price greater than \$25, perhaps to cover fixed costs, then the network will simply fail. This is true even though the network might be socially efficient. For example, when half the market ($f = 0.5$) or 500,000 consumers are served, we know that those who obtain the product are those consumers with v_i values in the range of \$50 to \$100. The average $v_i = \left(\frac{1}{50}\right)\sum_{I=51}^{100} v_i$ value for this group is therefore \$75. With $f = 0.5$, the average actual willingness to pay across these consumers is accordingly $1/2 \times \$75 = \$37.50$. As long

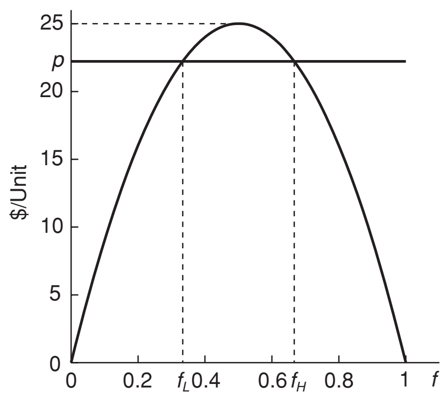

Figure 24.1 Demand to a monopoly provider of a network service
At price p if fewer than f_L consumers subscribe to the network, the equilibrium will fall to $f = 0$. If more than f_L consumers subscribe to the network, the equilibrium will rise to f_H.

as the price is below this amount, consumers as a group gain from having the network service available. Suppose that the monopolist could in fact provide service to 500,000 customers but to do so would require that it sink development costs of $15 million or $30 per customer. The firm would then have to charge a hook-up price of $30 just to break even.

Now $30 is certainly less than $37.50 so such an outcome would be desirable as it would generate net positive consumer gains and no producer losses. Moreover, with an average willingness to pay of $37.50, charging a fee of $30 may also appear to be a price that the market could support. Yet as we have just stated and as Figure 24.1 illustrates, the network will not be viable at this price. Why? Because while the average consumer valuation at $f = 0.5$ is $37.50, there are some current consumers (those for whom $\$50 \leq v_i < \$60$) whose willingness to pay is less than $30. As the price rises toward $30, these consumers drop the service. Some (those for whom $\$50 \leq v_i < \$52$) drop as soon as the price rises to $26, more drop as it hits $27 and so on. The loss of these consumers, however, reduces the value of the network to those remaining. Those who were previously just willing to pay $30 when the service had 500,000 subscribers, no longer will be willing to do so now that fewer people are signed on. These consumers will also cease to purchase the product reducing still further the network's value to the now even fewer customers left behind. This process will continue until the entire market unravels and the network fails. Here one can see the externality quite explicitly. A consumer does not consider the impact her choice to join or to leave the network has on the value of the network to others.

Next note that for prices less than or equal to $25, there is actually more than one equilibrium value of f. For instance, when $p = \$22.22$, both $f_L(p) = 1/3$ and $f_H(p) = 2/3$ are possible values for f. Which of these might we expect to occur? Rohlfs points out that the low-fraction equilibrium is actually unstable. Consider, for example, the effect of a small increase in the price or a small loss of customers. Starting from an equilibrium with so few subscribers, this would repeat the outcome described above. As a few consumers leave, the value of being part of the system to those remaining is reduced. Again, the eventual outcome is that all subscribers leave and the network fails. Now consider the impact of a small reduction in the price or the addition of one extra subscriber, again starting from the low-fraction equilibrium. This would increase the value of the service above the reservation price of all consumers in the interval $[0, f_H]$. It would therefore lead to the establishment of the high fraction, or $f_H(p)$, equilibrium. These thought experiments suggest that once the fraction $f_L(p)$ of consumers subscribes to the network, it is virtually certain that the high-fraction equilibrium will be attained, since only a trivial price reduction is necessary to do so. For this reason, Rohlfs refer to this lower fraction as a "critical mass" for the network. So long as a fraction of subscribers just a bit greater than this critical mass, $f_L(p)$, can be established, the network will grow to contain the high fraction, $f_H(p)$, of the population.

An important question therefore is whether and how the monopolist can reach the critical mass. For as we have just seen, values of f below the critical mass tend to unravel. That is, an alternative equilibrium that arises at the price of $22.22 is one in which no consumer signs up for the service at all. The reason that this can happen is fairly straightforward. At that price, no individual consumer will wish to sign up for the service unless others do. Accordingly, each consumer holds back from joining until they see some others hooking up. Hence, an outcome in which no one has joined the network can be self-sustaining.

The question as to how to get the network started and grow to a critical mass is an interesting one. One possibility is to provide the service free for a limited period of time. One way to accomplish such selling below cost is to bundle the service free with some other product. Another option is to lease the equipment to potential users with a guarantee that if the service does not achieve critical mass, the lease agreement can be canceled with no penalty. A further possibility, which was employed when fax machines were first being marketed, would be to target groups of large users first. In this regard, national and multinational companies or government agencies are the obvious examples of institutions that might want to operate their own internal networks. The idea is that once the network comes into common use for internal company communications, there will be a demand for it to be extended to those with whom the company does business. Before long, this may grow into a demand by company users of the service for it to be available in their homes.

For the moment, let us assume that the monopolist does achieve the critical mass. What fee will the monopolist charge for its services and how does this compares to the social optimum? In answering this question we will again assume that the monopolist's costs are all fixed and given by F, so that the marginal cost of adding a further subscriber to the network is zero. Let us also assume that the maximum number of individuals who would sign up even at a zero price is N. (In our example above, N = one million.) Then total profit to the monopolist is

$$\pi(f) = pfN - F = 100Nf^2(1 - f) - F \text{ given that } p = 100f(1 - f) \tag{24.4}$$

Maximizing this with respect to f indicates (see the inset) that the monopolist should choose p such that $f^* = 2/3$, implying a profit-maximizing price of $p^* = \$22.22$. As just described, actually getting two-thirds of the market to sign on at a price of $22.22 may be difficult until the critical mass ($f = 1/3$) is reached. Still, it is clear that this should be the monopolist's goal.

How does the combination $p = \$22.22$ and $f = 2/3$ compare with the social optimum? It should not surprise you that the profit-maximizing choice of the monopolist is to serve a smaller market than that which would maximize the total surplus. After all, monopolists achieve their profit by restricting output. The social optimum requires that the market be as large as possible at a price equal to marginal cost. In our case, this means that all N consumers should be served, i.e., $f = 1$.

Derivation Checkpoint
The Profit-Maximizing Network Access Price

Profit is $\pi(f) = pfN = 100Nf^2(1 - f) - F$. Differentiating with respect to f gives the first-order condition:

$$\frac{d\pi(f)}{df} = 100N(2f - 3f^2) = 0$$

This implies that either $f = 0$ or $f = 2/3$. The choice of $f = 0$ generates negative profits so long as $F > 0$. The choice of $f = 2/3$ generates positive operating profits (hopefully, enough to cover fixed costs F). Hence, $f^* = 2/3$ is the optimal choice of market share f. From the inverse demand function,

$$p = 100f(1 - f), \text{ a value of } f = 2/3 \text{ implies a price of } 100 \times \frac{2}{9} = \$22.22.$$

Consider for example the numerical example above with N = one million. At the monopolist's profit-maximizing price of \$22.22, two-thirds of the market or 666,666.66 consumers are served. The monopolist therefore earns a profit of \$14.81 million less fixed cost F. Consumer surplus may be calculated as follows. With two-thirds of the market served, all consumers with v_i values in the range $\$33.33 \leq v_i \leq \$100$, hook up to the service. Hence, the average value of v_i for this group is \$67.67. Since $f = 2/3$, the average willingness to pay of those consumers served in this equilibrium is $0.67 \times \$67.67 \approx \$45$. Hence, with $p = \$22.22$, the average consumer earns a surplus of \$22.78. Multiplying this average surplus by the 666,666.66 consumers yields a total consumer surplus of about \$15,187,000. Accordingly, the monopolist's profit maximizing price and quantity generates a total surplus of \$14.81 million + \$15.19 million = \$30 million *less* the fixed cost F.

Now consider the social optimum in which $f = 1$. With all one million consumers receiving the service, the average value of v_i (and therefore of fv_i) is \$50. Hence, the total value of the service is \$50 million. The total social surplus would then be \$50 million − F. Clearly, this exceeds the total surplus under monopoly. Of course, just how the optimal outcome would be achieved in practice is unclear. One way is through subsidization by the government. Alternatively, it could be achieved by creating a legal monopoly and permitting it to price discriminate. A combination of these two strategies is also possible. Indeed, one can think of the postal system as a giant network served by a government monopoly that is both subsidized and that price discriminates (e.g., express versus first class mail).

24.2 NETWORKS, COMPETITION, AND COMPLEMENTARY SERVICES

While the Rohlfs (1974) model focuses on the provision of network services by a monopolist, it makes clear many of the major difficulties that network externalities raise when competition is considered. The market could fail altogether. Alternatively, there could be more than one equilibrium outcome and there is no guarantee that the market will choose the best one. For example, suppose that there are two firms, firm A and firm B, competing for the 1,000,000–customer market above. Suppose further that while fixed costs are zero, each firm now has a positive marginal cost of \$11.11. Consumers buy the service of the network that gives them the biggest net surplus, $f_Av_i - p_A$, and $f_Bv_i - p_B$, respectively. In the case of a tie, consumers are split randomly between the two services. One possible equilibrium occurs with each firm setting a price $p_A = p_B$ = marginal cost = \$11.11 and two-thirds of the market being served. The firms offer identical products and, given the tie-breaking assumption, each serves half of the consumers ranging from valuations \$33.33 and up. However, since each firm individually serves only one-third of the market, the valuation of the least valuable consumer in each case is $fv_i = 0.333 \times \$33.33 = \$11.11$. Neither firm has an incentive to raise its price unilaterally. This would only lose customers and make its network even less valuable to consumers. Nor does either firm have an incentive to lower its price. While this may give it an edge in attracting customers, each one served now involves a loss as the firm would be selling below cost. Hence, $p_A = p_B = \$11.11$ and two-thirds of market being served is one possible equilibrium.

However, there are two other possible outcomes. They occur when either firm A or firm B has a monopoly with respect to all consumers actually subscribing to a network at the monopoly price while its rival has zero customers at a price equal to or greater than marginal cost. It is easy to show, for example, that with a marginal cost of \$11.11, the monopoly price would be \$23.89 and that at this price, the monopolist would serve about 60.5 percent of the market and earn a profit of \$12.78 on each customer. Suppose that firm A is doing precisely this while firm B is charging a lower price but has zero consumers. Clearly, firm A has no incentive to raise or lower its price since it already has set a price that maximizes its profit. Firm B has no incentive to change its price either. Raising it surely will not help it attract any customers. Yet lowering it won't either because no one will choose a network that has no other customers regardless of the price. Practice Problem 24.1 offers a simple but more complete model of competition with network effects.

Practice Problem 24.1

Two firms are located at opposite ends of a Hotelling line one unit long. Firm A is located at the West end of town ($x = 0$) and firm B is located at the East end of town ($x = 1$). $\bar{N}$ consumers are distributed uniformly along the line. Each buys at most one unit of the good either from firm A or firm B. The net surplus earned by a consumer is: $V + ks^e_A - tx - p_A$ if she buys from firm A, and $V + ks^e_B - t(1 - x) - p_B$, where s^e_A and s^e_B are, respectively, the market shares of consumers that the typical consumer *expects* to purchase good A and good B, respectively. V is large enough that consumers always buy from one of the two firms, i.e., the market is covered. Firms have zero costs and compete in prices, p_A and p_B, respectively. Note that the actual market shares for each good are, respectively: $s^A = x^m$ and $s^B = 1 - x^m$, where x^m is the location of the marginal consumer just indifferent between the two products of the two firms.

a. Assume as a benchmark, no-network-effects case that $k = 0$. Show that prices then are: $p_A = p_B = t$.
b. Now assume that $t > k > 0$.
   (i) Show that the marginal consumer x^m must satisfy the condition: $2tx^m = t + k(s^e_A - s^e_B) + (p_B - p_A)$.
   (ii) At the time that the marginal consumer confronts a particular set of prices, p_A and p_B, and makes her purchase choice she is aware of her marginal consumer status. She therefore forms the rational expectation that: $s^e_A = x^m$ and $s^e_B = 1 - x^m$. Impose this rational expectation requirement to show that the demand facing firm A, namely $N_A = x^m\bar{N}$ is: $N_A = \left[\frac{1}{2} + \frac{(p_B - p_A)}{2(t - k)}\right]\bar{N}$
   (iii) Show that profit maximization by firm A implies the best response function: $p_A = \frac{t - k}{2} + \frac{p_B}{2}$.
   (iv) Use the symmetry condition to show that the equilibrium prices are: $p_A = p_B = t - k$. Compare this result to the no networks effect case of part a.

Competition between two or more firms to establish the network can be particularly fierce if it is possible that only one firm or network survives, i.e., when the market has a "winner take all" feature. The winning network claims the entire (served) population and the loser gets nothing. The market is "tippy" in that once a firm starts to lose customers the value of its product to the remaining customers falls, causing it to lose more customers, its value to fall further, and so on. In such a setting, more than market share is at stake. Survival itself is on the line. Moreover, while this "winner take all" feature would greatly intensify the competition by itself, coupling it with an environment in which pricing below cost may be necessary just to get any network started, makes the competition truly nasty. Some economists have argued that it was precisely this dynamic that was at work in the *Microsoft* versus *Netscape* case and that what may look like predatory behavior when applied in other markets is really just normal competition when applied in a setting of network goods.[3]

Market problems become particularly difficult when the network is a system comprised of complementary components and when we consider what happens over time. Suppose for instance that the network in question involves the market for digital versatile disc (DVD) movies. The two components to this network are the DVD player and the movie discs themselves. This complementary relationship complicates the network effect. The desired outcome is for sufficiently wide use of DVD players and discs to achieve what appear to be rather sizable scale economies that characterize production, especially disc-making. However, no firm or group of firms will sink the large up-front costs necessary to produce a lot of DVDs unless they are sure that there will be a substantial number of DVD players. Yet consumers may be reluctant to purchase a DVD player until they are sure that there will be a large number of films translated to DVD's for playing. In such a setting one possibility is that the market fails completely because of self-fulfilling expectations. If no consumer expects DVD films to be widely available (or available at a low price), no one will invest in buying a DVD player and, as a result, no firm will produce many DVD films. In turn, this outcome will confirm the initial expectations, justifying the decision not to purchase a DVD player. On the other hand, an alternative outcome is that each consumer expects others to purchase DVD players and therefore anticipates that firms will find it worthwhile to put films on DVDs. In this case, each consumer will purchase a player, inducing firms to produce movie discs, which now confirms this more optimistic expectation. The network externality in this case is reflected in the fact that as I buy a DVD player, I enhance the value of your DVD machine because I increase the likelihood that there will be firms that find it worthwhile to produce DVD films.

The DVD example also highlights another aspect of the multiple equilibria problem, namely, the possibility that the particular equilibrium realized may be one in which the market is "locked" into the wrong or an inferior technology. From a durability and volume of information viewpoint, the DVD technology is undoubtedly superior and less costly way to provide movie rentals than is the VHS technology based on videocassettes and VCRs. However, because the two systems are substitutes and because VHS was the first system to get established, the DVD system has had to attract customers away from VHS in order to gain a footing. It might have been the case that the number of customers so attracted was not sufficiently large in order for the DVD manufacturers to exploit the available scale economies and avoid losses. To reach that volume, each potential DVD consumer needed not only to be convinced of the superiority of the DVD system but also to be sure that others shared that conviction and were willing to act on it. In this case, purely by the historical accident that the videocassette system was developed first, consumers would have been locked into the inferior system.[4]

3 See Schmalensee (2000) for a clear statement of the view that competition in network or, (what he calls) "winner take most" markets is likely to be extremely fierce and easily mistaken for predatory conduct when practiced by a dominant incumbent.

4 David (1985) has argued that the standardized QWERTY keyboard used initially by typewriters and now by all PC keyboards, is an example of path dependent lock-in to an inferior technology, with the superior one being the Dvorak keyboard. While Liebowitz and Margolis (1990) cast considerable doubt on this argument, the case nevertheless makes clear that such market failure is a real possibility. See also, Arthur (1989).

To put it somewhat differently, there is "path dependence" so that which system eventually claims the market is the result of an arbitrary process, but one that "locks in" that outcome for a considerable period of time. Instead of the VHS versus DVD example just give, consider a closely related one from the earlier days of home video, namely, the VHS versus Betamax versions of video cassette recorders (VCRs). Imagine that 40 percent of the population has a slight preference for VHS machines *if* the price and market share of these machines are identical to the price and market share of Betamax based products. Similarly, the remaining 60 percent have a slight preference for Betamax. However, these slight preferences can be overcome if one firm has a much larger market share because, again, no one really wants to buy a network product if it does not have a very large network of users. Finally, we assume that all consumers are not initially aware of the general home video market. Instead, they learn of it over time. Each week a few more consumers randomly find out about home videos and decide to buy a VCR of either a VHS or Betamax type.

On average, we would expect each new wave of new consumers to be comprised of 60 percent of Betamax preferring consumers and 40 percent of VHS preferring consumers. However, it is quite possible that, picking randomly, one could get a batch of new consumers who were comprised of say 90 or even 100 percent of those who prefer VHS. Starting from a point in which each system has equal market penetration, such a random draw could easily tip the market heavily in favor of VHS. Once that happens, then even those with a slight preference for Betamax will, in subsequent rounds, choose to buy a VHS machine because that network is so much larger that many more films are going to be printed for it. Hence, the small random draw favoring VHS may tip the entire market in favor of this technology forever even though, at base, Betamax is the superior technology in that most consumers favor it over VHS when all else is equal.

Similarly, Microsoft's dominance may reflect just plain good luck as much as it does superior technology. A key development in this regard came in 1980 when IBM decided to enter the personal computer market in a major way. IBM awarded the contract for its disc operating system to Microsoft and MS-DOS was born. Many analysts think that Microsoft did not have the best product at that time. Yet having the support of IBM was clearly a major advantage in establishing a network of MS-DOS users. Note that the network effect gives Microsoft a strong defense against Linux or Apple or some other product even if it is a better operating system than Windows. Again, the lock in effect raises the possibility that the market may adopt the inferior technology.

24.3 SYSTEMS COMPETITION AND THE BATTLE OVER INDUSTRY STANDARDS

Competition between systems does not always lead to one survivor. There are four major suppliers of long distance phone service (MCI/WorldCom, Sprint, Verizon, and AT&T) now active in the U.S. domestic market. There is roughly the same number of wireless phone providers. When we allow for the coexistence of two or more firms, each operating its own network, a number of additional features enter into the analysis. In such cases, there is the important issue of compatibility. To what extent will the industry adopt a standard product design that enables consumers to "plug in" to any network? If a standard is adopted, what standard will it be? In this section, we address these and related questions using a simple illustrative model described below.

Consider for example the question of technology adoption. Assume that two firms have to decide on whether to stick with their individual, existing technology or switch to a new one. To be specific, suppose that the firms estimate the payoffs to their choices to be those shown in Tables 24.1(a) and 24.1(b). The distinction between these two matrices is that in (1) sticking with the old technology is less profitable jointly than incurring the installation costs of switching to the new technology, while in case (2) both firms switching reduces their joint profits.

The payoff received for either firm depends critically on what choice its rival makes. However, there is also a further complication, namely, the issue of compatibility. Suppose that the old technology and the new technology are incompatible in the sense that they cannot be used together. This means that if each firm makes a different choice, they do not derive any network benefits of the type we have introduced previously. By contrast, if they choose the same technologies—whether old or new—then they do enjoy network externalities. Such positive network externalities mean that the payoff to each firm if they choose the same technology is greater than if they choose different technologies. This is illustrated in the payoff matrices by the fact that the payoff to either firm when both firms choose the same technology, no matter which, is greater than the payoff to either firm when they choose different (incompatible) technologies.

Regardless of whether both would do best by switching to the new technology (Table 24.1(a)), or both would do best by avoiding the cost of installing the new equipment and sticking with the existing technology (Table 24.1(b)), it can be seen that there are two Nash equilibria: one in which the two firms stay with the old technology, and the other in which they both switch to the new technology. There is no simple way to pick between these two

Table 24.1 Excess inertia and excess momentum with network externalities (in U.S. dollars, millions)

		Firm 2	
		Old technology	*New technology*
Firm 1	*Old technology*	5, 4	3, 2
	New technology	3, 3	6, 7

(a) The new technology is Pareto superior to the old. A Nash equilibrium with both firms staying with the old technology exhibits excess inertia.

		Firm 2	
		Old technology	*New technology*
Firm 1	*Old technology*	6, 7	3, 2
	New technology	3, 3	5, 4

(b) The old technology is Pareto superior to the new. A Nash equilibrium with both firms adopting the new technology exhibits excess momentum.

equilibrium outcomes. If the payoffs are as in Table 24.1 (a) and so both switching is efficient, each firm may nevertheless choose not to switch from fear of moving alone into an incompatible technology. Farrell and Saloner (1985) refer to this as a case of excess inertia. Alternatively, with the payoffs of Table 24.1(b), we might find excess momentum with both firms making a costly switch to the new technology out of fear of being stranded alone with the old technology.

There are, of course, ways by which the firms can attempt to avoid either of these unsatisfactory outcomes. For example, the firms might be able to communicate their proposed technology choices—and they have the incentive to do so honestly since lying actually hurts both firms. Coordination may also be more likely if we extend this game over many periods, since then a firm has the potential to correct a "wrong" choice, i.e., one different from that of its rival. Nevertheless, even in these more general settings, Farrell and Saloner show that firms may in particular delay switching technology longer than they should. That is, rather than move promptly to introduce new technology soon, they may wait unduly long until a sufficiently large "bandwagon" has built up. Thus, some theater owners and film producers in the 1920s did not invest in the equipment to show or to make "talking pictures" until they were certain that the new phenomenon would catch on. As a result, the advent of "talkies" may have been suboptimally delayed.

Compatibility is clearly an important factor in technological choice. However, there is a drawback to compatibility. When each firm adopts the same technical standard, their products become very close substitutes and so price competition is likely to be intense. Hence, while product differentiation by means of different technologies incurs the cost of foregoing possible network effects it has the benefit of softening price competition. Firms therefore have to make a judgment in this regard. Choosing the same technology will lead the firms into direct, intratechnology competition of the type discussed throughout the earlier chapters of this book—that is, competition on price, quality, and service. By contrast, the choice of different technologies will lead the firms into intertechnology competition.

Of course, if a firm can establish its technology as the industry standard, the rewards from this kind of competition are likely to be very large indeed. When firms choose to compete in different technologies each is hoping that its technology will someday win the market and become the industry standard. Think of Sony's PlayStation, Nintendo's Wii, and Microsoft's Xbox. These three firms apparently regard the advantages of compatibility to be more than offset by the disadvantages that it would bring in terms of intensified price competition. As a result, the three systems are totally incompatible. Yet each hopes to win the market and to establish its technology as the standard for which all applications, i.e., games are written.

There is no a priori means of determining whether rewards will be greater under intratechnology competition "within the market" or intertechnology competition "for the market." There are, however, three main possibilities that we should consider. We illustrate these with three simple games: (1) Tweedledum and Tweedledee, (2) The Battle of the Sexes, and (3) The Pesky Little Brother.[5]

Tweedledum and Tweedledee

Assume that the payoffs for this game of technology choice are given in Table 24.2. There are two Nash equilibria in each of which the firms prefer to adopt incompatible technologies.

[5] This analysis is developed in depth in Besen and Farrell (1994). The language that follows is also borrowed from their discussion.

Table 24.2 Tweedledum and Tweedledee (in U.S. dollars, millions)

		Firm 2	
		Technology A	*Technology B*
Firm 1	*Technology A*	3, 2	8, 4
	Technology B	4, 8	2, 3

Two firms prefer to choose incompatible rather than compatible technologies and will become involved in a standards war.

This implies that the firms believe that network externalities are not particularly strong and that any gains from adopting a common technology will be more than offset by the fact that this will lead to particularly fierce intratechnology price competition. They also believe that a battle to establish the industry standard will not significantly delay its adoption by potential consumers and so offers large rewards.

With these payoffs, each firm willingly enters into a battle to have its technology established as the dominant one, i.e., each will push for the Nash equilibrium that favors its own product. In terms of the game matrix, Firm 1 will fight to establish its technology as the "A" technology, thereby defining firm 2's as the lesser "B" technology, and firm 2 will do exactly the same. Besen and Farrell (1994) suggest four forms that this battle can take:

1. *Build on an early lead*: If there are any network externalities at all associated with a particular technology of the type we have discussed, there is considerable benefit to a firm that succeeds in establishing a large installed base of current users. These users will be reluctant to switch to a different technology. At the same time, the existence of such a large installed base makes the technology attractive to new users. (Just think of the choice that a new computer user has to make between buying an IBM compatible running the Windows operating system against a similar machine running Linux or an Apple computer with the Apple operating system.) Under this scenario, there will be intense price competition in the early stages of new technologies as each firm attempts to capture as many customers as possible. Firms will also reveal and perhaps exaggerate their sales figures in order to persuade potential buyers that a large installed base already exists.
2. *Attract suppliers of complements*: As we have pointed out many times, the attractiveness of a product is affected by the number of complementary products that are also available. A computer is of little use except to the most advanced users unless there is a wide range of computer software that will run on it. A Nintendo game machine becomes more attractive as Nintendo or other firms expand the number of games it can play. There is little point in owning a CD player unless recording companies offer a wide range of recordings in CD format.

   Owners of a primary technology such as Dell or Microsoft will likely encourage software developers to produce a wide range of programs that will run on their platform. Indeed, one reason that Apple lost its early lead in personal computers may well have been its reluctance to have its operating system installed in clones. This restriction limited the market penetration of Apple's system and consequently reduced the incentives of software developers to produce Apple-compatible software.

3. *Product preannouncement*: The owner of a particular technology can try to slow the growth of a rival network by regularly "preannouncing" new products in advance of their actual introduction. The idea is to discourage new buyers from choosing the rival's product with the promise of new "goodies" to come. The long-advertised arrival of Microsoft's Vista program may have been in part an effort to attract new buyers who might otherwise have started out buying an alternative operating system. Such a strategy is not without risk, however. Announcing that a new version of a dominant product is just round the corner may not just cause some new customers to delay their purchase of a rival's product. It may also cause customers already favorable to one's existing product to delay their purchases as well.
4. *Price commitments*: A contractual commitment to achieve and maintain low prices over the long term is a fourth method by which new consumers can be persuaded to adopt a particular technology. This will be especially beneficial if the firm offering the commitment knows that there are significant economies of scale or learning economies in the manufacture of the primary product. In such circumstances, building a large installed base early generates cost reductions that allow the firm to deliver on its low price while maintaining its profitability.

In short, when rival firms compete to establish an industry standard, a variety of strategies and outcomes emerge. Here again we find that such markets are "tippy" with multiple equilibria in which the coexistence of incompatible products may be unstable. The tide of battle can turn rapidly and quite suddenly a dynamic can develop that leads to a single winning standard dominating the market. Moreover, there is no guarantee that the winner will offer the best technology.

The Battle of the Sexes[6]

Rather than fight to have their own technology adopted as the industry standard, firms may agree on the adoption of a common technology. The payoff matrix in this case is as in Tables 24.3(a) and (b). The simplest case is that illustrated in Table 24.3(a). Here, both firms are agreed that they should adopt technology 1. Accordingly, they should be able to establish this technology as a common standard by simple communication between them.

In the case of Table 24.3(b), however, there is no such agreement. The firms would prefer a common standard but they are not agreed on which of the two technologies the standard should be. Firm 1 will fight to establish technology 1 as the standard, and firm 2 will fight to establish technology 2. This is another instance in which commitment plays a crucial role. Firm 1, for example, may be able to persuade firm 2 to accept technology 1 as the standard by irrevocably committing itself to this technology. It could, for example, build an installed base rooted in technology 1. Alternatively, it could invest in production capacity to build more units embodying this technology, or establish a large R&D program devoted to improving this technology. The common intent here is to broadcast the clear message that firm 1 will never give in on its demand that technology 1 be the standard because to do so would cost firm 1 too much to give in.

[6] This title comes from a well-known game in which two individuals, perhaps man and wife, in choosing their entertainment for the night, agree that they would rather be together than apart, but put very different valuations on the entertainment they might share. These could be, for example, going to a ball game or to an opera.

Table 24.3 The Battle of the Sexes (in U.S. dollars, millions)

		Firm 2	
		Technology 1	*Technology 2*
Firm 1	*Technology 1*	10, 10	5, 4
	Technology 2	6, 5	8, 8

(a) Agreement on compatible standard and choice of standard.

		Firm 2	
		Technology 1	*Technology 2*
Firm 1	*Technology 1*	8, 12	5, 4
	Technology 1	6, 5	10, 7

(b) Agreement to be compatible but disagreement on standard.

Other possible commitments take the form of concessions rather than threats. Thus, firm 1 could offer to license technology 1 to firm 2 for a low fee in return for firm 2 agreeing that technology 1 will be the standard. Alternatively, firm 1 can promise to develop the technology jointly, or it can suggest that the two firms develop a hybrid technology that combines the best features of each.

The Pesky Little Brother

In the Tweedledum and Tweedledee case, the two firms pursue inter-technology competition rather than adopt a common technology and confront each other in the market with technologically undifferentiated products. In The Battle of the Sexes, each firm prefers competition between technically identical products, but the question of which technology is the appropriate standard remains an issue. What these two cases have in common is that there is some degree of consensus, if only on the terms on which competition between the firms will occur. If, however, there are asymmetries between the firms, it may be impossible for them to reach even this limited kind of consensus.

Assume, for example, that firm 1, has established a dominant position with a large installed base and a powerful reputation. It will prefer incompatibility with a small rival in order to hold its customers. The smaller rival, firm 2, will prefer compatibility in order to derive benefits from the network that the larger firm has established. As Besen and Farrell indicate "The firms' problem is like the game between a big brother who wants to be left alone and a pesky little brother who wants to be with his big brother."

The payoff matrix now looks something like Table 24.4. There is no Nash equilibrium (in pure strategies) to this game if the firms make simultaneous choices—the two firms'

Table 24.4 The Pesky Little Brother (in U.S. dollars, millions)

		Firm 2	
		Technology 1	*Technology 2*
Firm 1	*Technology 1*	12, 4	16, 2
	Technology 2	15, 2	10, 5

There is no (pure strategy) Nash Equilibrium in simultaneous play. Firm 1, the dominant firm (or big brother) prefers that the technologies be incompatible. Firm 2 (the little brother) prefers that they be compatible.

strategic choices are inconsistent.[7] Resolution of the game then comes down again to a question of timing and commitment.

Suppose that the dominant firm must commit to its technology choice first. This is perhaps the most plausible assumption, given that we have motivated the game by describing firm 1 as a preexisting firm with a large installed base. In this case, the smaller firm 2 may actually enjoy a second-mover advantage. If firm 1 is committed to its existing technology either because it is costly to change or because such change would lose firm 1 the guaranteed patronage it now enjoys from its customers, it may be unable to prevent firm 2 from following. In this case, firm 2's clear choice will be to follow with a compatible system, precisely the outcome firm had hoped to avoid.

Two tactics might be available to firm 1 that would prevent firm 2 from imitating its lead and offer firm 1 relief from its "pesky little brother." These are: (1) aggressive protection of its property rights and (2) changing its technology frequently. The first tactic relates to the use of patents. If the technology the dominant firm has built up is protected by patents, then imitation may be preventable through strict enforcement of the protection such patents give and by building up a stock of sleeping patents that make it difficult for a smaller firm to invent around the current technology.

Alternatively, firm 1 can try to hamper firm 2's imitation efforts by changing its technology frequently. This, of course, can be expensive and runs the risk of alienating users of the existing installed base unless they can be protected by, for example, being given favorable access to the new generation of products. The advantage to this approach is that the target at which the smaller rival is aiming is constantly shifting in ways that are difficult for the small firm to predict. If you really want to avoid your pesky little brother, don't tell him where you are going!

In short, competition over technology has a variety of implications. Often, there may be large social gains from all firms adopting a common technical approach. But the incentive for firms to differentiate their products, as well as the rivalry over which technology should become the industry standard can frequently thwart the realization of such gains. While the gains from price competition are generally clear, the network externality effects make the gains from technology competition more ambiguous.

[7] With a game of this type with a finite number of strategies, there is always a Nash equilibrium in mixed strategies in which the firms randomize their choice of technologies, but we shall not consider this equilibrium.

Reality Checkpoint
The Battle for a High (Definition) Standard

In the later 1970s, Sony introduced the BetaMax technology for videocassette recorders (VCR's) and thereby also initiated the war with the Video Home System (VHS), initially engineered by JVC Corporation, over the format standard for VCRs. Of course, Sony eventually lost that war. VHS won out as the standard and a lot of consumers found themselves owning an increasingly obsolete BetaMax machine as more and more films were issued in VHS format. Then DVDs came along. Now, some thirty years later, Sony is involved in another battle over the format for television reproduction technology.

Sony is one of a number of electronics firms pushing the Blu Ray technology for the next generation of DVDs that will support high-density (HD) broadcasts. Its rival, Toshiba, and its allies however, have opted for a different format known technically as the Advanced Optical Disc (AOD) format. Both technologies use a shorter wavelength blue-violet laser technology, in contrast to the 650nm-wavelength red laser technology used in traditional DVD formats. As a result, the modern technologies use a finer beam and are capable of storing and reading a much greater amount of information than the older DVD technologies.

Each side has a lot at stake and has fought hard to make its technology the industry standard. For its part, Sony has built the Blu Ray technology into its Play Station 3 game console. In addition, it has directed its film studios (including MGM) to issue high-density DVDs only in Blu Ray format, and persuaded both Fox and Disney to do the same with their films. The Toshiba group, which includes Microsoft, has countered by incorporating the AOD format into Microsoft's XBox 360 console and by getting Universal to restrict its high-density DVD film releases to this format, as well. Paramount and Warner are currently issuing HD DVDs in both formats.

All this has been bad news for retailers and consumers. Store owners are not sure which format of film to stock. Customers have been reluctant to buying a high-definition disc player not knowing whether it will become the next BetaMax machine or not. Of course, low sales for HD disc players also means low sales for HD DVDs. The only hope so far has been the emergence of machines that can play both formats. The South Korean firm, LG Electronics has begun to market such a machine and others may soon follow. Unfortunately, the current price for such a machine, just over $1,000, is about the same as one would pay to buy two separate machines, one using Blue Ray technology and one using the AOD format.

At present, Blu Ray seems to have the advantage in terms of support from Hollywood and other film-makers issuing films in its format. Yet the alternative HD machines generally sell for less than a Blu Ray player. So, as of this writing, it remains anyone's guess as to which will format will ultimately win this standards war. Both use a laser that's violet blue but until the battle is over, a lot of people will mostly be seeing red.

Source: N. Wingfield, "Format Face-Off: Bringing the DVD War Home," *Wall Street Journal*, June 20, 2006, p. D1; and W. Mossberg, "Don't Get Caught in a Losing Battle over DVD Technology," *Wall Street Journal*, March 8, 2007, p. B1.

24.4 NETWORK GOODS AND PUBLIC POLICY

Our analysis of network services suggests many ways in which the market mechanism may fail to produce an efficient outcome. In some cases, a socially desirable service may fail to be provided. In other cases, multiple possible outcomes raise the possibility that the market may choose the wrong equilibrium and lock into an inferior technology. Competition may not be a feasible market structure. Moreover, even where feasible, competition may not be a remedy for these failures. To the contrary, competition may intensify the rush to a particular standard or technology, which later is realized to be inferior. Competition may also lead firms to reject compatibility even when it might actually be desirable. When the market will only support one system or network, competition is likely to be very intense and border on predatory conduct. How should public policy deal with these issues?

It is important to understand that in many respects, the problems raised by network effects are not new. The presence of dramatic scale economies and externalities have long been recognized as potential sources of market failure. Large scale economies make marginal cost pricing unlikely because such large scale economies means that marginal cost is below average cost over a wide range of production. Further, even when it is possible to operate at a sufficiently large size that all the scale economies are exploited, doing so will likely imply that there is room for only a few firms. Similarly, externalities always imply a divergence between private and social benefit (or cost) with the result that market outcomes based on the maximizing choices of individuals and firms are not likely to be optimal.

Saying that the problems raised by network effects are not new, however, is not the same thing as saying that they are easy. Three problems are particularly difficult in the case of network goods. The first of these is the problem of detecting or proving anticompetitive behavior. The second is the difficulty of devising an appropriate remedy once anticompetitive actions have been identified. The third is determining the proper role that the government should play in coordinating the technology choices of different firms with a view towards achieving standardization.

Consider the problem of determining anticompetitive tactics. The presence of network externalities requires that the developer of a new product such as a facsimile machine sell to a large number of consumers in order to establish any market at all. In turn, this may well mean pricing below cost, at least initially. This may result in a competitor being driven out of the business. When later, the winning firm raises its price so as to earn a return on its investment, the historical record of selling below cost, eliminating a rival, and then raising price looks a lot like a case of predatory pricing. Indeed, such a record is essentially the evidence called for by Baumol (1979) to determine predation. (See Chapter 13.) Yet such a finding may simply reflect the need to price low so as to penetrate the market and the fact that the market can only support one supplier.

Similarly, the developer of a platform such as Windows or Wii or a DVD player requires that there be a large number of applications (programs, games, or films) available at a low cost in order to gain wide acceptance of the overall system. One way to achieve this aim is to produce and market such complementary goods itself. Yet to the extent that one can only play Nintendo Wii cartridges on a Nintendo Wii machine the market outcome begins to look like illegal tying or possibly an attempt at foreclosure. To borrow from an example earlier in the text, Microsoft's Windows almost certainly gained from the availability of a compatible, low cost web browser. Yet Microsoft's decision to bundle its Explorer browser with Windows raised substantial concerns of tying with a view to driving Netscape out of the browser business.[8]

[8] This point was made forcibly by Schmalensee (2000). See Fisher (2000) for an opposing point of view. Note that if Schmalensee's argument is that in some industries, e.g., web browsers, only one firm can survive this is really a statement that such a market is a natural monopoly of the type described in Chapter 2. The only difference being that here the scale economy lies on the demand side via the network externality. See also Eisenach and Lenard (1999).

With regard to technology adoption and product improvement, the case of Microsoft is again relevant. Sun Microsystems' Java programming language offered the possibility of greatly enhancing the functionality of Windows. However, this required that Windows be made compatible with Java. Microsoft was generally reluctant to do this at least in part because there was a widespread view that Java could provide the basis for an alternative applications platform if it ever became widely accepted. Making it compatible with Windows would have this effect. So, while providing that compatibility might greatly improve the technology available for PC users, it might also provide an opportunity for entry to a new rival. Does Microsoft's reluctance in this case reflect an illegal effort to deter entry?[9]

As difficult as it is to identify anticompetitive behavior in network or systems markets, devising an appropriate remedy when such actions are discovered is perhaps even more problematic. The just mentioned case of Microsoft and Sun Microsystems is instructive in this connection. Is the appropriate policy to force Microsoft to make Windows compatible with Java? Adoption of such a policy would place the government in the awkward position of pushing a particular technology, and it is far from clear that the government has the skill to do this well. What If *Java* really does not offer any real improvement on the Windows product? Indeed, what if there is an alternative programming language that would offer much greater enhancement? That alternative may never break through if antitrust officials require that Windows work with Java. In other words, antitrust policy may also result in an inferior technology lock-in.

This raises the general question as to the proper role for the government in coordinating the technology choices of different firms with a view towards achieving standardization. Consider the market for mobile telephone service. As a result of legislation by the European Parliament, all mobile phones in Europe adhere to the same technical standard. Consequently, a British resident traveling on the continent can use her mobile phone to make calls in Italy just as easily as she can at home. This was much less feasible for U.S. residents, in part, because there was no centralized authority coordinating the digital standard of American mobile phone companies. Instead, the mobile phone services in the U.S. initially adopted four different standards and inter-service communication was impossible. On the other hand, the presence of these different standards has led to increased competition and technical development. As mobile phone companies in the U.S. have expanded their coverage over wider and wider areas, the regional reach of an American consumer has become comparable to that of a European one with the American consumer enjoying the added benefit of systems competition and technical advance.

24.5 EMPIRICAL APPLICATION
Network Externalities in Computer Software—Spreadsheets

As noted earlier, computer software such as operating systems and web browsers are likely to exhibit important network effects. Users care about being able to run their programs on the computers of their friends or business associates. The more people using a specific software package or the more compatible a software package is with add-on programs, the more valuable it should be. Gandal (1994) offers empirical evidence of this phenomenon from the early days of desktop computing.

[9] Microsoft and Sun eventually did reach an agreement of sorts, but Sun was never happy with it and the agreement was later abandoned.

A spreadsheet was initially a pencil-and-paper operation. Essentially, it was large sheet of paper with columns and rows organizing all the relevant data about a firm's transactions. Its name comes from the fact that costs or revenues connected to a specific operation were spread or displayed over the sheet in a manner allowing sums over a given row or column. In that way, management is able to focus on a specific factor, say energy costs, in making an informed decision about company operations. The advantage of a spreadsheet format is that if a given cost factor or revenue assumption is change, decision-makers can trace through the implications of this change rather quickly. However, there is a natural limit to the speed of such adjustments when spreadsheets are "hard copy" and changes must be made by hand.

Beginning about 1980, electronic spreadsheets suitable for use on desktop computers began to make their commercial appearance. The first of these was VisiCalc (Visible Calculator). Computerization greatly enhanced the speed with which managers could assess the impact of cost or revenue changes. It thereby greatly increased the usefulness of spreadsheets in daily operations. Demand for such products grew and so did the supply. Soon, there were a number of spreadsheet programs including SuperCalc, VP Planner, PlanPerfec; Quatro Pro, Multiplan, Excel, and Lotus 1–2–3.

These early products differed both from each other and over time. The earliest versions had very limited, if any, graphing abilities. Some could link entries in one spreadsheet to others in another spreadsheet. Some could not. Only a few were able to link with external data and incorporate that data into the spreadsheet cells directly. The most flexible of all was the Lotus 1–2–3 program. Throughout the late 1980s and into the 1990s, this was the dominant product. Indeed, an important attribute of other spreadsheet programs was whether or not they were Lotus compatible.

Gandal (1994) notes that spreadsheet demand will likely exhibit network effects for a number of reasons because users like to be able to share their information and the results of their spreadsheet analyses with each other. Gandal then identifies three features of a spreadsheet program that should promote such networking. The first is whether or not the program was compatible with Lotus 1–2–3, the dominant product. This is measured by a variable *LOCOMP* equal to 1 if the program is Lotus compatible and 0 if it is not. The second network attribute is *EXTDAT*. This is a variable that takes on the value 1 if the program can import files from external data sources and 0 if it cannot. The final network feature is another 1,0 variable *LANCOM* that indicates whether or not the program can link independent users through a local area network.

Gandal (1994) hypothesizes that if network externalities are present in the spreadsheet market, then a program's market price will be higher if it has any of the three features just described, i.e., when for that product, any of the variables *LOCOMP*, *EXTDAT*, or *LANCOM* is positive. A function that specifies how product price changes as the product's attributes change is known as an hedonic function. Estimating such functions is usually done by ordinary least squares (OLS) in an hedonic price regression. Gandal (1994) gathered data for 91 computerized spreadsheet products over the six years, 1986 through 1991. His basic regression equation is:

$$\begin{aligned}\ln p_{it} = {} & \alpha_0 + \alpha_1 TIME87_t + \alpha_2 TIME88_t + \alpha_3 TIME89_t + \alpha_4 TIME90_t + \alpha_5 TIME91_t \\ & + \beta_1 LMINRC_{it} + \beta_2 LOTUS_{it} + \beta_3 GRAPHS_{it} + \beta_4 WINDOW_{it} \\ & + \gamma_1 LOCOMP_{it} + \gamma_2 EXTDAT_{it} + \gamma_3 LANCOM_{it} + \varepsilon_{it}\end{aligned}$$

The dependent variable is the natural log of the price of spreadsheet model *i* in year *t*. Not including the constant, the first five variables are time dummy variables equal to 1 if the year is that indicated by the dummy and zero otherwise. These variables pick up the pure effects of time on spreadsheet program prices while holding the quality attributes fixed. The next four variables are variables that pick up specific features that should add to the value of a spreadsheet program. *LMINRC* is the natural log of the minimum of the maximum number of rows or columns that the spreadsheet can handle. This is meant to capture the sheer computing power of the program. *LOTUS* is a 1,0 dummy variable indicating whether the product is a Lotus spreadsheet. This term captures any brand premium that Lotus enjoyed during these years. GRAPHS is a 1, 0 dummy variable indicating whether or not the program can construct pie, bar, and line graphs. *WINDOW* indicates the number of windows a program can handle on a screen simultaneously. Of course, the last three variables are the networking effects described earlier. If there are network externalities, the coefficients on these variables should be significantly positive.

Gandal's (1994) results are presented in the Table 24.5. The first regression shown is the estimated hedonic equation described above. Note that all the attributes hypothesized to raise the value of a spreadsheet program do in fact exert a significantly positive effect on its price. There is a strong brand premium for Lotus. There is an almost as strong premium for programs that have graphing abilities. Most important of all however, the three networking variables are very strongly positive. *LOCOMP*, *EXTDAT*, and *LANCOM* all have a substantial positive effect on a program's price.

Regression 2 shows the effects of allowing the coefficients to change over time. Gandal (1994) splits the sample in half and adds as regressors, values of the independent variables multiplied by 1 if the observation comes in the second half of the sample. Most of these interacted variables are not significant. However, the coefficients on both *MINRC* and *LINKING* do change over time as indicated by the coefficients on *TMINRC* and *TLINKING*. These coefficients are interpreted as the difference between the marginal value of these features in the first half of the sample and that value in the second half of the sample. Note that this

Table 24.5 Hedonic regression results for spreadsheet programs, 1986–91

Variable	*Regression 1*		*Regression 2*	
	Coefficient	*t-statistic*	*Coefficient*	*t-statistic*
CONSTANT	3.76	(12.31)	3.12	(9.50)
TIME87	–0.06	(–0.38)	–0.07	(–0.43)
TIME88	–0.44	(–2.67)	–0.45	(–3.03)
TIME89	–0.70	(–4.20)	0.92	(1.71)
TIME90	–0.79	(–4.90)	0.90	(1.67)
TIME91	–0.85	(–5.30)	0.85	(1.59)
LMINRC	0.11	(1.59)	0.26	(3.24)
LOTUS	0.56	(4.36)	0.46	(3.62)
GRAPHS	0.46	(3.51)	0.52	(4.18)
WINDOW	0.17	(2.14)	0.14	(1.92)
LINKING	0.21	(1.91)	0.26	(2.00)
LOCOMP	0.72	(5.28)	0.66	(5.17)
EXTDAT	0.55	(4.05)	0.57	(3.93)
LANCOM	0.21	(1.65)		
TLANCOM			0.61	(3.28)
TLMINRC			–0.34	(–3.07)
TLINKING			–0.31	(–1.49)

Table 24.6 Quality adjusted price indices for spreadsheet programs, 1986–91

	1986	*1987*	*1988*	*1989*	*1990*	*1991*
Price index from regression 1	1.00	0.94	0.64	0.49	0.45	0.42
Price index from regression 2	1.00	0.93	0.64	0.50	0.48	0.46

regression includes *TLANCOM* but not *LANCOM*. This is because connecting to local area networks was generally not possible for any program prior to the second half of the sample.

Gandal (1994) prefers Regression 2 as the better specification of the hedonic price equation. Note again that it implies strong network externalities. The coefficients on *LOCOMP*, *EXTDAT*, and *TLANCOM* are all very significantly positive. Consumers are willing to pay a lot extra for spreadsheets that others can use either because they are Lotus-compatible, can easily import data from external programs, or can exchange information over a local area network. These effects are powerful. Because the dependent variable is the log of the price, the coefficient is easily interpreted as the percentage increase in price a consumer would pay for that feature. Thus, being Lotus-compatible raised the price of a spreadsheet program by 66 percent according to Gandal's (1994) estimates. A program's ability to import data from an external source raised the price by 57 percent.

A frequent use of hedonic price regressions is to construct price indices that trace the movement of a commodity's price over time. This is often difficult to do because we do not have an easy way to adjust for quality. A television set today may cost much more that a television set from ten years ago. However, it would be wrong to interpret all of that price increase as inflation since today's television set has many more features than that of an earlier set such as high definition, DVD compatibility, and a flat screen, to name just a few. Because the hedonic regression controls explicitly the value of quality features, it permits the easy construction of a quality-corrected price index by focusing on the changes that are due simply to the passage of time, i.e., holding quality constant. In Regression1, these changes are fully captured by the year specific dummies. Since the dependent variable is ln p_{it}, the predicted price for a spreadsheet of constant quality in any year: $p_{it} = e^{\alpha_t YEAR_t}$ where the $YEAR_t$ variable the dummy for that observation and α_t is the coefficient estimated for that dummy. If we normalize so that the price index P_t is 1 in the first year of 1986, then equation 1 says that the price index will be $e^{-0.06}$ in 1987; $e^{-0.44}$ in 1988; and so on. For Regression 2, constructing the quality-adjusted price index is slightly more complicated because the value of the some of the attributes also changes over time, but the basic idea is the same. We present Gandal's (1994) estimated spreadsheet price indices for both regressions below (Table 4.6). It indicates that over the six-year period for which Gandal (1994) collected data, the quality-adjusted price of spreadsheet programs—like the price of much software and hardware in this time period, declined substantially. Here, the decline exceeded 50 percent.

Summary

In this chapter, we have focused on the product markets exhibiting important "network externalities." In such markets, the value of the good or service to any one consumer increases as the total number of consumers using the product increases. Services with important network effects, such as telecommunications and home electronics, play an increasingly large role in modern economies.

Markets with strong network effects present special problems. Competition to establish a network service can be unusually fierce, leading to low prices that can be difficult to distinguish from predation. Often, such competition will result in only one firm surviving so that the market's ultimate structure is one of monopoly. There is also a nontrivial risk that the service will be underdeveloped or not developed at all. Similarly, the course of technical development exhibits a path dependency in which the market may eventually lock into an inferior technology.

There are no easy solutions to the problems raised by network goods. On the one hand, the possibilities for anticompetitive outcomes seem sufficiently clear that such markets necessarily invite examination by the antitrust authorities. Yet it must also be acknowledged that it is not easy either to identify anticompetitive actions clearly or to devise workable remedies to the market failures to which network services are prone. Such tensions have dominated the debate over policies regarding the telecommunications industry and other "new economy" markets in the past. They will no doubt continue to be important in the future.

Problems

1. Two banks compete for the checking and savings deposit business of a small town. Each bank has its own ATM network that works only on its own bankcards, but bank 1 has three times as many ATM machines as bank 2. Depositors value a bank's services as an increasing function of the number of machines on the network. Bank 2 approaches bank 1 and suggests that they merge their ATM networks so that depositors of either bank can use either bank's machines.
   a. Is this merger in the interest of deposit consumers in general?
   b. Do you think that bank 1 will agree with bank 2's proposal?

2. Assume that consumers contemplating buying a network service have reservation prices uniformly distributed on the interval [0, 50] (measured in dollars). Demand by a consumer with reservation price w_i for this service is:

$$q_i^D = \begin{cases} 0 \text{ if } fw_i < p \\ 1 \text{ if } fw_i \geq p \end{cases}.$$

   a. Calculate the demand function for this service.
   b. What is the critical mass if price is set at $5?
   c. What is the profit-maximizing price for the service?

3. Many social customs exhibit network effects. To this end, consider a party given by a group of individuals at a small university. The group is called the Outcasts and has 20 members. It holds a big party on campus each year. These parties are good, but are especially good the more people in attendance. As a result, the number of people who actually come to the Outcasts party depends on how many people are expected to attend. The more people that are expected to attend, the more fun it will be for each attendee and, hence, the more people who actually will come. These effects are captured by the following equation: $A = 20 + 0.95A^e$. Here, A is the number of people actually attending the party. This is equal to the 20 Outcast members plus 0.95 times the number of partygoers A^e that are expected to go.
   a. If potential party attendees are sophisticated and understand the equation describing actual party attendance, how many people are likely to attend the Outcasts party?
   b. Suppose that each party attendee costs the Outcasts $2 in refreshments so that the Outcasts need to charge a fee p for attending the party. Suppose as well that when going to the party requires paying a fee, the equation for attendance is: $A = 20 + 0.95A^e - p$. What value of p should the Outcasts set if they want to maximize their profit from the party? How many people will come to the party at that price?

4. Two firms are competing in their choice of technologies. The payoff matrix for the game between them is given by
   a. Identify constraints on the payoffs a–h that are such that the firms' choices reflect network externalities.

b. Assume that the constraints in (a) are satisfied. Identify further constraints that must be satisfied for the game between the two firms to be of the form
   (i) Tweedledum and Tweedledee,
   (ii) The Battle of the Sexes,
   (iii) The Pesky Little Brother.

		Firm 2	
		Technology 1	Technology 2
Firm 1	Technology 1	a,b	c,d
	Technology 2	e,f	g,h

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