■ **15.7***** A large fraction of industry entry corresponds to acquisition of incumbent firms. For example, from a sample of 3,788 entry events, about 70% were acquisitions.[41] Econometric analysis suggests that entry by acquisition is more common in more concentrated industries.[42] Can you explain this observation?

Suggestion: Consider a Cournot oligopoly with n symmetric firms. Determine the maximum that an entrant would be willing to pay for one of the incumbent firms. Determine also the minimum that an incumbent would require from a buyer, *knowing that the alternative to selling the firm is for the entrant to create a new firm.* Show that the difference between the two values above is greater when the industry is more concentrated.[43]

What other factors would you expect to influence the "build or buy" decision when entering an industry?

Solution: Suppose that $p = a - bQ$ and $c(q) = cq + F$. Every firm solves $\max[(a - c - bQ)q - F]$, with the solution being $q_i = \frac{a-c}{b(n+1)}$. In a symmetric equilibrium all firms produce the same quantity, and the profits would be $\pi_i^{(n)} = \left(\frac{a-c}{n+1}\right)^2 \frac{n}{b} - F$. Therefore, a buyer is willing to pay up to $\left(\frac{a-c}{n+1}\right)^2 \frac{n}{b} - F$ to aquire an incumbent firm. If the buyer decides to enter, the number of firms in the industry becomes $n+1$, hence each firm's profit is given by $\pi_i^{(n+1)} = \left(\frac{a-c}{n+2}\right)^2 \frac{n+1}{b} - F$. This is also the minimum that a target would require.

The difference is given by $\Delta = \pi_i^{(n+1)} - \pi_i^{(n)} = \left(\frac{a-c}{n+1}\right)^2 \frac{n}{b} - \left(\frac{a-c}{n+2}\right)^2 \frac{n+1}{b} = \frac{(a-c)^2}{b}\left(\frac{n(n+2)^2-(n+1)^3}{(n+1)^2(n+2)^2}\right) = \frac{(a-c)^2}{b}\left(\frac{n^2+n-1}{(n+1)^2(n+2)^2}\right)$. $sign(\frac{\partial \Delta}{\partial n}) = sign(-2n^3 - 3n^2 + 5n + 8)$, which is less than 0 for any n greater or equal to 2.

In industries with a large number of firms, the value of a potential target does not go down to much if the potential acquirer enters by building a new plant. Adding one more firm in an industry with a big number of players results in a marginal decrease in profits. On the other hand, if the industry is concentrated, adding one more firm leads to a large drop in profits, hence, the potential target prefers to be acquired.

One other reason why acquisition may be thought of as a good strategy is the time necessary to build a new plant. Acquisition gives the right to the firms profits in a "short" time, while a new plant needs time to become established as a player in the industry.

41

Porter, Michael (1987), "From Competitive Advantage to Corporate Strategy," *Harvard Business Review*, May-June, 43–59..

42

Caves, Richard E., and Sanjeev Mehra (1986), "Entry of Foreign Multinationals into U.S. Manufacturing Industries," in Porter (Ed), *Competition in Global Industries*, Cambridge, MA: Harvard Business School Press..

43 This exercise is adapted from

Gilbert, Richard, and David Newbery (1992), "Alternative Entry Paths: The Build or Buy Decision," *Journal of Economics and Management Strategy* **1**, 127–150..

■ **16.1** "Perfect competition is not only impossible but inferior, and has no title to being set up as a model of ideal efficiency." Do you agree? Why or why not?

Solution: In a static sense, perfect competition is the most efficient industry structure, since it maximizes social welfare. In a dynamic sense, however, perfect competition is not necessarily the ideal model, since it may be less conducive to technological progress than situations that allow for some (temporary) degree of market power. The latter would not necessarily be monopoly markets (in a static sense) but rather forms of oligopoly, in which firms compete not only in quantity (or price) but also in R&D, so that they can outpower rivals in the future and gain some market power.

■ **16.2** "ĉompetition implies a dynamic system whereby industries tend to become more and more concentrated." Do you agree? Why or why not?

Solution: There is no clear answer to this question. The reason why industries would move towards a higher concentration is the presence of a steep learning curve (see the case of the wide-body aircraft manufacturing industry). If one of the firms is moving faster down the learning curve than its rivals, it can end up in a position where its competitive advantage is big enough so that it remains the sole major player in the industry.

On the other hand, we saw that if there is uncertainty regarding the threat of entry, outsiders have a greater incentive to perform R&D, which implies a higher lielihood of entry and the industry becomes more competitive.

■ **16.3** Two firms are engaged in Bertrand competition. There are 10,000 people in the population, each of whom is willing to pay at most 10 for at most one unit of the good. Currently, both firms have a constant marginal cost of 5.

(a) What is the equilibrium in this market? What are the firms' profits?

(b) Suppose that one firm can adopt a new technology that lowers its marginal cost to 3. What is the equilibrium now? How much would this firm be willing to pay for this new technology?

(c) Suppose the new technology mentioned in (b) is available to both firms. The cost to a firm of purchasing this technology is 10,000. The game is now played in two stages. First, the firms simultaneously decide whether to adopt the new technology or not. Then, in the second stage, the firms set prices simultaneously. Assume that each firm knows whether or not its rival acquired the new technology when choosing its prices. What is (are) the Nash equilibrium (equilibria) of this game? (What does your answer suggest about why firms engage in patent races?)[44]

Solution:

[44] Adapted from Haas School of Business economics problem sets.

(a) Both firms charge $p = 5$ and earn $\pi = 0$.

(b) The firm with the lower cost technology charges a fraction of a cent less than $p = 5$ and sells to all 10,000 customers. Its profits are $\pi = [(5 - 3) \cdot 10,000] = 20,000$. It would be willing to pay up to 20,000 for this technology.

(c) There are two pure-strategy equilibria: (1) firm 1 invests in the low-cost technology and firm 2 does not, and (2) firm 2 invests in the low-cost technology and firm 1 does not. It is not an equilibrium for both firms to invest or for neither firm to invest. (There is also a mixed strategy equilibrium in which each firm invests with probability 0.5.)

■ **16.4*** In 1984, the U.S. Congress passed legislation that allowed generic-drug makers to receive fast marketing approval from the Food and Drug Administration (FDA). Since then, the market share of generic-drug companies has increased considerably (in volume). Branded-drug companies have attempted different tactics to protect their market share. In some cases, large pharmaceutical firms have paid generic firms to keep off the market. Ivax Corp. and Novartis AG, for example, have agreed not to market a generic competitor to Abbott Laboratories' hypertension drug Hytrin. In exchange, Abott pays quarterly fees totaling several million dollars.[45]

Compare this example to the discussion on the persistence of monopoly power.

Solution: Suppose for simplicity that Abbot Laboratories is a monopolist on the hypertension drug market. From Section 16.2, we know that a monopolist has a greater incentive to maintain its monopoly power than a rival has to enter. In other words, the monopolist has more to loose from competition than the rival has to gain (the efficiency effect). There are therefore potential gains from an agreement like to one described above.

■ **16.5** Patent life is 17 years in the U.S. and 20 years in Europe. From the perspective of social welfare, do you find this period too short or too long?

Solution: The discussion in Section 16.3 suggests that it is optimal to provide relatively weak patents for relatively long periods of time.

■ **16.6** Should firms be allowed to enter into agreements regarding R&D?

Solution: R&D agreements between firms help alleviate the free-rider problem occuring due to the inevitable spillovers from R&D activity. Moreover, such agreements help reduce the risk associated with an R&D project. There might also be important synergies stemming

[45] *The Wall Street Journal Europe*, November 19, 1998.

from the combination of experience, intellectual and mental resources and so on. On the other hand, if spillovers are low and the gain from R&D to a firm is a loss to another, then R&D joint ventures may lead to an undesirable reduction in R&D expenditures. See Section 16.3.

■ **17.1*** You have created a business-to-business (B2B) Internet venture directed at an industry with exactly fifty (50) identical firms. Your services allow these firms to do business with each other more efficiently as members of your trading network. You plan to sell access to your service for a price p per member firm. Each firm's benefit from the service is given by $2n$, where n is the number of other firms joining the B2B network as a member. So, if 21 firms join your service, each places a value of 2×20 or 40 on membership in your network.

Suppose for part (a) that you set the price, p, and then firms simultaneously and independently decide whether or not to join as members.

(a) Show that, for a price greater than zero and lower than 98, there exist exactly two Nash equilibria in the simultaneous-move game played by firms deciding whether or not to join the network as members.

Suppose for part (b) that you are able to persuade 10 firms to join your network at an initial stage as "Charter Members." At a second stage, you set a price for the remaining 40 firms. These 40 firms then simultaneously decide (as in part (a)) whether to join your network as regular members.

(b) For each price p, determine the equilibria of the game played between the remaining 40 firms in the second stage.

Finally, for part (c), consider the same situation as in part (c), but suppose that, when there are multiple Nash equilibria, firms behave conservatively and conjecture that the low-adoption Nash equilibrium will be played. (Note that, by the definition of Nash equilibrium, this conjecture is self-fulfilling.)

(c) How much would you be willing to pay (in total to all 10 early adopters) in order to persuade the first 10 firms to join the network as Charter Members?

Solution:

(a) Suppose that no firm joins the network. Then the benefit for an individual firm to join the network is zero. If price is positive, the net benefit is negative, which implies that it is a best response not to join the network, which in turn confirms the conjecture that no firm joins the network. We thus have a Nash equilibrium where no firm joins the network for any positive price.

Suppose now that each firm conjectures that all of the other firms will join the network. The expected benefit from joining the network is therefore $98 = 2 \times 49$. If price is less than 98, the net benefit is positive, which in turn confirms the conjecture that all firms join the network. We thus have a Nash equilibrium where all firms join the network for a price less than 98.

Suppose that you are able to persuade 10 firms to join the network at an initial stage. At a second stage, you set a price for the remaining 40 firms. These 40 firms then simultaneously decide whether to join the network (as in (a)).

(b) Each of the second-mover firms knows that the number of adopters is at least 10. It follows that the benefit from joining the network is at least $2 \times 10 = 20$. Therefore, if price is less than 20, then the zero-adoption equilibrium is no longer a Nash equilibrium. Only the full-adoption equilibrium remains. For higher prices, however, the two equilibria are possible, for the same reasons as in (a).

Suppose that, when there are multiple Nash equilibria, firms behave conservatively and conjecture that the low-adoption equilibrium will be played. (Note that, by definition of Nash equilibrium, this conjecture is self-fulfilling.)

(c) If no firm joins the network in the first stage, then the game in the second stage is as described in (a). Since for any positive price there are two equilibria and firms behave "conservatively", it follows that no firm joins the network in the second stage and profits are zero. If however the 10 firms do join the network at the initial stage, then, in the second stage, you can set a price of up to 20 and know that all firms will join the network (since this is the only Nash equilibrium and firms know that; in fact, joining the network would be a dominant strategy). For a price $P = 20$, this leads to profits $20 \times 40 = 600$. We conclude that you should be willing to spend up to 600 to persuade the first 10 firms to join the network.

■ **17.2** Empirical evidence suggests that, between 1986 and 1991, consumers were willing to pay a significant premium for spreadsheets that were compatible with the Lotus platform, the dominant spreadsheet during that period.[46] What type of network externalities is this evidence of?

Solution: One can think of this both as a type of direct and indirect externality. For example, exchanging files with users of the Lotus package, one has to own a compatible spreadsheet. This is a case of direct network externality. On the other hand, developments in the Lotus software can (potentially) be easily adapted and adopted by compatible software products, which is a case of indirect network externality.

■ **17.3** People are more likely to buy their first home computer in areas where a high fraction of households already own computers or where a large share of their

[46] See

GANDAL, NEIL (1994), "Hedonic Price Indexes for Spreadsheets and an Empirical Test for Network Externalities," *Rand Journal of Economics* **25**, 160–170..

friends and family own computers: a ten percent greater penetration in the surrounding city is associated with a one percent higher adoption rate.[47] How can this be explained by network externalities? What alternative explanations are there?

Solution: The larger the number of households/friends that own computers, the larger the the possibilities for direct communication among users and the greater utility one derives from owning a computer. Communication among users may consist of email exchange, learning how to use a given software, exchange of files, and so forth.

An alternative explanation is that certain areas attract more "sophisticaded" users than other areas. If this were the case, those areas would have a higher penetration rate and a higher adoption rate. But then the correlation between penetration and adoption would be just that—correlation, not causality. Another situation of correlation-not-causality is when a higher penetration implies a greater degree of competition in the computer market, lower prices and a higher adoption rate.

See the cited reference for additional alternative explanations.

■ **17.4**** In the early days of Automated Teller Machines (ATMs), there were very few interbank networks, that is, each bank's network was incompatible with the other banks'. Empirical evidence shows that banks with a larger network of branches adopted ATMs earlier. To what extent can network externalities explain this observation?[48]

Solution: Network effects imply that the value of using a given ATM system is increasing in the number of ATM machines compatible with that system. Part of the value created by a network is gained by the consumer, part by the banks. Assuming (as is empirically observed) that the cost of adoption is decreasing over time, the above observation implies that the critical moment in time at which it pays to adopt ATMs is earlier the greater the netowrk effect. Since the number of branches is a good proxy for the number of ATMs, this implies that banks with a greater number of ATM machines are likely to adopt first, as the evidence shows was indeed the case.

■ **17.5** How would you respond to the following quotation:

47

Goolsbee, Austan, and Peter J Klenow (1998), "Evidence on Learning and Network Externalities in the Diffusion of Home Computers," University of Chicago..

48 See

Saloner, Garth, and Andrea Shephard (Adoption of Technologies With Network Effects: An Empirical Examination of the Adoption of Automated Teller Machines), "Rand Journal of Economics," *26* **479–501**, ..

> Apple Computer, the company that brought you the idiot-friendly Macintosh, is staring at bankruptcy. Meanwhile, the great army of technocrats at Microsoft, which only last year managed to reproduce the look and feel of a 1980's Mac, lumbers on, invincible.
>
> A bad break for Apple? A rare exception to the Darwinian rules in which the best products win the hearts and dollars of consumers?[49]

Solution: This is an instance of how network externalities work and how "the best technology" does not always win. As in Section 17.2, it is possible that the lock-in to the Microsoft operationg system resulted from a series of "small historial events," not from the inherent superiority of the Microsoft operating system.

■ **17.6*** Consider the model of technology adoption presented in Section **??**. Suppose that the utility derived by an A fan from technology A is given by $u + n_A$ if n_A is less than $\bar{n}_A$, and $u + \bar{n}_A$ for values of n greater than $\bar{n}_A$. Likewise utility from buying technology B is as before except that for n_B greater thank $\bar{n}_B$ we get $\bar{n}_B$. Analogous expressions apply for B fans. In other words, network externalities are bounded: once the network reaches a certain size, no additional benefits are gained from a larger network.

Show that, under these circumstances and for certain values of u, v, three different outcomes are possible: (a) the industry becomes locked-in to technology A; (b) the industry becomes locked-in to technology B; (c) the two technologies survive in the long run.

Solution: One can distinguish 3 cases:

a) If $u + \overline{n_A} \leq \overline{n_B}$ then all future adopters will prefer technology B;

b) If $u + \overline{n_B} \leq \overline{n_A}$ then all future adopters will prefer technolgy A;

c) If $u + \overline{n_B} = \overline{n_A}$ or $u + \overline{n_A} \leq \overline{n_B}$ then adopters that would prefer technology B (and respectively A) are indifferent, therefore both technologies will survive.

■ **17.7** Explain why the market adoption of a new technology may be too fast or to slow.

Solution: The adoption of new a technology may feature excess inertia because of incomplete information about the preferences of future potential adopters. Even a slight probability that future users are conservative and therefore are better off not adopting the new technology, can act as a deterrent for early users that would prefer the new technology.

On the other hand, excess momentum may appear when sticking to the old technology is not a dominant strategy. That is, if initial users prefer the new technology, future users

[49] *The New York Times Magazine*, May 5, 1996.

will also choose the new technology, despite the fact that the utility from sticking to the old technolgy if the initial users were also conservative, is much higher (see the example in section 17.3).

■ **17.8** Company A has just developed a new technology. Company B approaches Company A, stating it has developed its own version of the technology and proposing a compromise that would make the two technologies compatible with each other. What advice would you give Company A?

Solution: If the firms decide to go alone, standards competition reduces the product-market size for both of them, and they may end up loosing, since users have the easy option of staying with the old technology (see the example in box 17.3). Therefore, compatibility is the prefered action.

On the other hand, if product competition is fierce when the products are compatible, then the two firms will get duopoly profits which are lower than the expectation of profits from refusing the compromise (case in which each firm receives monopoly profits with probability 0.5). In this case, the decission to go alone is better.

■ **17.9** A standardization battle is currently under way in the recordable DVD industry, with Philips and Sony on one side, Matsushita and Toshiba on the other side. In an effort to coordinate on a standard, an industry group was set up: the DVD Forum. On April 1997, the forum's ten members voted eight-to-two to standardize around the Matsushita-backed format, leaving Philips and Sony stranded with their losing format. Within a few weeks, Philips and Sony announced they would start selling their own format.

What role can you see for public policy in this case?

Solution: A standardization war can have as an effect a delay in the introduction of a product, which is bad both for the consumers and producers. Hence, there is scope for public policy in settling the issue of which standard should be chosen. On the other hand, the cost of having only one standard is lower product variety and lower competition. Public policy has to weigh which effect is more important from the point of view of social welfare.

■ **17.10*** You are marketing a new wireless information device (WID). Consumers differ in their willingness to pay for the device. (No one needs more than one.) All consumers value owning a WID more highly, the larger is the total number of consumers using such devices. Denote the expected total number of WID users by n^e, which we also can call the "expected size of the WID network."

If all consumers expect the size of the WID network to be n^e, and the price of the device is p, then the number of users who will want to buy the device (i.e., the total quantity demanded) is given by $n = 100 - p + vn^e$, where $0 < v < 1$. (Note that this is a standard linear relationship between price and unit sales for any given level of expected network size, n^e.)

(a) Interpret the parameter v. What factors influence v?

Suppose that your marginal cost per WID is 20. Suppose also that consumers are quite sophisticated and form accurate expectations about the size of the WID network, for any price p that you might set, so that n must equal n^e.

(b) What is the profit-maximizing price of WIDs? How many are sold, and what profits do you earn?

Suppose that you could improve the performance of your WID communications network and thus enhance the network effects, raising v from 1/3 to 1/2.

(c) How much would you pay to develop this enhancement?

Solution:

(a) The parameter v is the network benefit contributed by each additional WID sold. One way to think about this is as follows. When an additional WID is sold, n^e increases by one. This raises the benefit to all consumers from owning a WID since now there is one more WID out there with which they might communicate. Adding up this small improvement in the value of a WID for all consumers gives us the parameter v.

Suppose that your marginal cost per WID is 20. Suppose also that consumers are quite sophisticated and form accurate expectations about the size of the WID network, for any price p that you might set.

(b) Since consumers have accurate expectations we can set n^e equal to n and invert the total demand for WIDs to get $p = 100 - (1 - v)n$ as the inverse demand curve and a marginal revenue curve of $MR = 100 - 2(1 - v)n$. The optimal number of WIDs to sell is that which equates this marginal revenue with marginal cost. That is, $100 - 2(1 - v)n = 20$ or $n = (80)/2(1 - v)$. The profit maximizing price is then $p = 100 - (1 - v)(80)/2(1 - v) = 60$ and profits are $(60 - 20)80/2(1 - v) = 1600/(1 - v)$.

(c) When $v = 1/3$, the firm's profits are $1600/(1 - .333) = \$2,400$. When $v = 1/2$, the firm's profits are $1600/(1 - .5) = \$3,200$. Therefore, the most the firm would pay to develop this enhancement is \$3,200-\$2,400=\$800.

■ **17.11*** Two firms, Compress and Squeeze, offer incompatible software products that encrypt and shrink the size of large data files for safe storage and/or faster transmission. This software category exhibits strong network effects, since users seek to send files to each other, and a file saved in one format cannot be retrieved using the other format. The marginal cost of serving one customer is \$40 for either firm.

To keep things simple, suppose that there are only two customers, "Pioneer" and "Follower," and two time periods, "This Year" and "Next Year." As the name

suggests, Pioneer moves first, picking one format This Year. Pioneer cannot change her choice once it is made. In contrast, Follower picks Next Year. Follower will be aware of Pioneer's pick when the time comes for Follower to pick. The annual interest rate is 20% for both Compress and Squeeze and Pioneer.

Pioneer regards Compress and Squeeze as equally attractive products. Pioneer values either product at \$100 during This Year (before Follower enters the market), and at \$100 during Next Year if Follower does not pick the same product. If Follower does pick the same product Next Year, Pioneer's value during Next Year will be \$136. (In other words, the network effect is worth \$36 to Pioneer.)

Follower has very similar preferences. If Follower picks the same product Next Year as Pioneer did This Year, Follower values that product at \$136. Alternatively, if Follower picks a different product Next Year than Pioneer did This Year, the value to Follower of that product will be only \$100.

Finally, suppose that Compress and Squeeze simultaneously set prices This Year at which they offer their products to Pioneer. (One could just as well say that they bid for Pioneer's business.) Then Compress and Squeeze simultaneously set prices Next Year at which they will offer their products to Follower.

For simplicity, please assume that Pioneer will pick Compress if Pioneer is just indifferent between Compress and Squeeze, and that Follower will pick the same product as Pioneer if Follower is indifferent between Compress and Squeeze given the values they offer and the prices they charge.

(a) What prices will Compress and Squeeze set Next Year in bidding to win Follower's business if Compress wins Pioneer's business This Year?

(b) What prices will Compress and Squeeze set This Year in bidding to win Pioneer's business?

(c) What product will Pioneer buy, and what product will Follower buy?

(d) What are the resulting payoffs of Compress, Squeeze, Pioneer, and Follower?

(e) Describe in words the advantages of early or late adopters identified in this problem.

(f) How does all of this change if there is rapid technological progress so that costs Next Year are much lower than costs This Year?

(g) How does your analysis change if the (marginal) cost of serving a customer is only 20 rather than 40?

Solution:

(a) If Compress wins during the first period, then Compress offers an extra \$36 value over Squeeze to Follower. Squeeze will compete as best possible by offering its product at cost, \$40, but Compress can win by charging \$76. (We could make this \$75.95, but the numbers are simplified by breaking ties in favor of Compress.)

(b) The equilibrium derived in A generates profits Next Year to Compress of \$36, which are equal to \$30 in This Year dollars (given the 20% interest rate). By symmetry, Squeeze would also enjoy profits of \$36 Next Year if Pioneer picks Squeeze this year. This implies that both Compress and Squeeze are prepared to set a price as low as \$10 to win Pioneer's business: losing Pioneer's business means they will lose Follower's business as well and earn

zero; bidding $10 means losing $30 This Year and earning profits of $36 Next Year, which gives zero in present discounted value.

(c) From the answer to B, we conclude that the Nash Equilibrium involves a bid of $10 by each firm to serve Pioneer. Compress thus will win Pioneer's business, by our tie-breaking convention. Then Squeeze will bid $40 to serve Follower, and Compress will bid $76 to serve Follower. Compress will win, so both customers will buy from Compress.

(d) Both firms earn zero profits in present discounted value. All of the profits are dissipated by bidding for Pioneer's business, since Pioneer "tips" the market towards one product or the other. Pioneer gets a surplus of $90 This Year and $136 Next Year. Follower gets surplus of $60 Next Year.

(e) Pioneer enjoys a nice strategic advantage by virtue of its ability to "tip" the market, i.e., to influence subsequent adopters.

(f) With rapid technological progress, prices fall rapidly and Follower could well do better than Pioneer, simply because Follower can buy when the product is much cheaper to produce (or of higher quality). From the customer's perspective, waiting for products to improve must be balanced against the benefits of adopting early and thus enjoying very strong price competition between incompatible suppliers seeking to build their installed bases and thus gain competitive advantage.

(g) If marginal costs are only $20, then the price during This Year would be -$10. The problem here is that many "phantom" customers could appear, take the $10 subsidy to use the product, and then disappear. Actually paying customers to take your product can be a very dangerous strategy. Are you building an installed base of users or just giving away money to opportunistic "fake" customers?

■ **17.12*** Technological progress (of a sort) has led to the WalkDVD. As the name suggests, this is a miniature DVD player. It is attached to a pair of headphones and special viewing glasses which, together, allow for highly realistic sound and image effects, as well as easy mobility. Three firms, Son, Tosh and Phil, are planning to launch their WalkDVD players. There are two possible formats to choose from, S and T, and the three competitors have not agreed on which standard to adopt. Son prefers standard S, whereas Tosh prefers standard T. Phil does not have any strong preference other than being compatible with the other firms. Specifically, the payoffs for each player as a function of the standard they adopt and the number of firms that adopt the same standard are given by Table 2. For example, the value 200 in the Son row and S2 column means that if Son chooses the S standard and two firms choose the S standard, then Son's payoff is 200.

Suppose that all three firms simultaneously choose which standard to adopt.

(a) Show that "all firms choosing S" and "all firms choosing T" are both Nash equilibria of this game.

Table 2: Payoffs in standard setting game.

Firm	S1	S2	S3	T1	T2	T2
Son	100	200	250	40	80	110
Tosh	40	80	110	100	200	250
Phil	60	100	120	60	100	120

(b) Determine whether there are any other Nash equilibria in this simultaneous-move game.

Son has just acquired a firm that manufactures DVDs for the S format. For all practical purposes, this implies that Son is committed to the S format. It is now up to Tosh and Phil to simultaneously decide which format to choose.

(c) Write down the 2x2 payoff matrix for the game now played by Tosh and Phil. Find the Nash equilibrium of this game.

(d) Do you think Son's move was a good one? How would your answer differ if Phil had a slight preference for the T format (e.g., assume that payoffs for T1, T2 and T3 are 70, 110 and 130, respectively)?

Suppose now that all firms' payoffs are like Phil in the table above. You are Son.

(e) If you could choose, would you rather move before Tosh and Phil, or after them? Contrast your answer to what you have learned from the answers to parts (c) and (d).

Solution:

(a) Suppose all firms choose S. By unilaterally deviating and choosing T instead, Son would get 40 instead of 250; Tosh would get 100 instead of 110; and Phil would get 60 instead of 120. Since all would stand to lose, we conclude that all with S constitutes a Nash equilibrium. By the same token, all choosing T is also a Nash equilibrium.

(b) The only other possible (pure-strategy) Nash equilibria are for two firms to choose one standard and one to choose the other one. But such a situation cannot be a Nash equilibrium: the firm that is the sole adopter of one of the standards would be better off by joining the other firms. We conclude that there are no (pure-strategy) Nash equilibria in addition to the ones derived in the previous question.

Son has just acquired a firm that manufactures DVDs for the S format. For all practical purposes, this implies that Son is committed to the S format. It is now up to Tosh and Phil to simultaneously decide which format to choose.

(c) The game is as follows:

		Phil: S	Phil: T
Tosh	S	120, 110	60, 80
	T	100, 100	100, 200

Notice that Phil has a (weakly) dominant strategy: to choose S. Even if Phil assigns the lowest positive probability that Tosh is going along with S, it is strictly better off (in expected value) by choosing S. Knowing this, Tosh should choose S, since, conditional on Phil choosing S, payoff is greater with S (110) than with T (100). We conclude that both firms choose S.

Notice that (T,T) is also a Nash equilibrium. However, the discussion above implies that it would not be a very "reasonable" Nash equilibrium.

(d) Son's move was a brilliant one. In the simultaneous-move game, there are two Nash equilibria, one that is good for Son, one that is not so good. By moving ahead of the other players, Son is effectively able to lead the industry to adopt its preferred standard.

In the event Phil prefers the T standard, things are different. The game played between Tosh and Phil is now the following

		Phil: S	Phil: T
Tosh	S	120, 110	70, 80
	T	100, 100	110, 200

There are now two Nash equilibria: (S,S) and (T,T). Moreover, joint payoff are greater in the (T,T) equilibrium (310) than in the (S,S) equilibrium (230). It is not unlikely that Tosh and Phil choose T, in which case Son is worse off by choosing S than by choosing T as well.

Suppose now that all firms' payoffs are like Phil in the table above. You are Son.

(e) If all firms have payoffs as Phil, then a particular firm would prefer to move after the other firms have moved than to move at the same time. As in part A, there are two Nash equilibria in the simultaneous-move game. Moreover, both equilibria yield each firm the same payoff. If firms are able to coordinate perfectly on which equilibrium to choose, then moving at the same time or after does not make a difference. If however there is a small chance that coordination will fail, then moving later is (weakly) better, as it reduces the probability of mis-coordination.

■ **17.13***** Consider the market for a given piece of hardware —a photocopier of brand x, for example— that needs after-sale servicing. Suppose that there is free entry into this after market. Servicing photocopiers implies a fixed cost of κ and a marginal cost of γ per unit of service provided. Total demand for servicing is given by $D = \sigma(\alpha - p)$, where p is price and σ the number of photocopier owners. Finally, suppose that firms in the after market compete *à la* Cournot.

Show that consumer surplus (per consumer) in the after market is given by

$$U = \frac{1}{2}\left(\alpha - \gamma - \sqrt{\frac{\kappa}{\sigma}}\right)^2,$$

an increasing, concave function of σ. (Hint: apply the results on Cournot competition with free entry derived in Chapter **??**. Take into account the fact consumer surplus per consumer is given by $(\alpha - p)^2/2$.)

Relate this result to the discussion on indirect network externalities (at the beginning of the chapter).

Solution: We have $p = a - \frac{Q}{S}$ and $q_i = \frac{(a-c)S}{n+1}$, $(\frac{a-c}{n+1})^2 = \frac{F}{S}$ and $n = \left[(a-c)\sqrt{\frac{S}{F}} - 1\right]$ (see derivation in 14.10). Consumer surplus is given by $CS = \frac{(p(0)-p^*)Q^*}{2} = \frac{Q^{*2}}{2S}$. Therefore, consumer surplus per consumer is $U = \frac{CS}{S} = \frac{Q^{*2}}{2S^2} = \frac{n^2}{2S^2}\frac{(a-c)^2S^2}{(n+1)^2} = \frac{n^2F}{2S} = \frac{1}{2}[(a-c)\sqrt{\frac{S}{F}} - 1]^2\frac{F}{S} = \frac{1}{2}(a - c - \sqrt{\frac{F}{S}})^2$.

This is a case of indirect network externalities. The greater the market size (S), the greater the need for after-sale services, and hence the greater competition in the after-sale market. This increase in competition lowers the price for after-sale services and increases consumer surplus.