Chapter 3
Oligopoly in International Telecommunications*

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INTRODUCTION

The telecommunications industry is unlike any other industry in one important respect: The fundamental output of the industry is communication, or more broadly, information flows between individuals or among groups of individuals. In order to satisfy any reasonable demands for all such information flows, it is necessary to construct a communications network of great complexity. In principle, this network knows no international boundaries. As the costs of long distance transmission of messages continue to fall, one can expect an ever-increasing demand for communication across international boundaries.

The global communications network is not, however, organized as a natural monopoly. Individual nations, and political jurisdictions within some nations, retain the right to regulate the industry within their boundaries. Even if all political jurisdictions agreed on the proper organization of the industry within their boundaries, there would remain important issues of coordination and control of the total network. This, more or less, represented the status quo prior to the agreement in 1982 between the American Telephone and Telegraph Company and the United States Department of Justice,[1] in which it was agreed that control over long distance communications would be

* This chapter represents the author's opinions and not necessarily those of Bell Communications Research, Inc.

separated from control over short haul communications and access to the network.[2] As a result of this agreement there is competition in the United States interexchange communications markets, and it is the policy of the Federal Communications Commission to encourage such competition, and to eventually remove all regulatory restraints in this portion of the network.

The official competition policy in the United States is not the only change in the worldwide status quo in the organization of telecommunications networks. In all countries, technology is advancing at a rapid pace. New technologies, such as fiber optics, offer the potential of a dramatic increase in communication capacity at a reasonable cost. New information-processing technologies offer the prospect of services that have never before been provided. In many respects the industry today resembles the industry nearly a century ago, soon after the invention of the telephone.[3] Together, the impact of changing technologies and the deregulation of certain portions of the global communications network create a new environment for both the managers of telecommunications companies and their regulators or governmental overseers. New problems of coordination and control now arise. Instead of the relatively simple bargaining problems between national monopolies, there is now the potential for complicated strategic interactions among competing firms within a country, which allows competition, and firms outside the country, whose cooperation is necessary in any transnational communication flow.

Economists can contribute to the understanding of these new forms of competition. However, there has so far been relatively little analysis of the problems of deregulation in network industries. The objective of this chapter is to begin to fill this gap. Specifically, I will consider several different models of oligopoly in international telecommunications in which telecommunications firms in two or more countries interact strategically. The goal will be to examine the nature of the equilibria of the resulting noncooperative games, and in particular the potentially undesirable consequences that oligopolistic equilibria may have.

The organization of the chapter will be as follows. Section 2 will consist of an overview of the advantages and disadvantages that might be associated with the growth of competition in telecommunications markets. Section 3 will describe the more technical models of noncooperative competition on some simple international networks. Examples of both leased-line networks and switched services will be considered. In these examples, which assume a constant returns to scale technology, a pure strategy equilibrium can be shown to always exist. That is, a price or quantity choice exists for each firm that maximizes profits, assuming the other firms maintain their chosen strategy. In other networks with two or more firms on one link and prices as the strategic variable, in general only mixed strategy equilibria exist. In these cases each firm has a probability distribution of prices that is optimal against its rivals' strategies, but there is no set of individual prices that satisfies the equilibrium conditions. The nonexistence of pure strategy equilibria is not really surprising when there are fixed costs of production. However, there may also exist only mixed strategy equilibria when marginal and average costs are constant, and when firms compete in different markets. This may happen in a triangular network with competition on only one of the three possible links. It may also happen more generally if firms have a cost advantage in one market but are able to compete effectively in more than one market.

When pure strategy equilibria exist, they are generally inefficient due to insufficient coordination between firms in different countries. These inefficiencies exist even if each country's market is a monopoly. However, in some cases, increased competition in one country has the effect of increasing the equilibrium price in the monopoly market of another country.

AN OVERVIEW OF COMPETITION IN INTERNATIONAL MARKETS

In the United States prior to the divestiture of AT&T, there was entry by firms in the markets for long distance telecommunications.[4] Today entry into long distance markets continues, entry into local telecommunications markets has begun, and there is the potential for entry into almost all sectors of the industry. In the international arena there are also many possible markets in which competitive entry might occur. International competition might take the form of entry by an affiliate of one nation's carrier into competitive markets of another country. Even if transnational entry does not occur, there are important problems associated with coordination across national boundaries when the policy is procompetitive on one side, and promonopoly on the other side. Finally, the potential for intermodal competition between satellites and terrestrial carrier systems is much greater in international than in domestic markets.

Some have argued that telecommunications markets are rapidly becoming "naturally competitive" (Fowler, Halprin, & Schlichting, 1986; Huber, 1987). The advantages of a competitive marketplace are well known and do not require elaboration here. In the context of a network industry, these advantages include the elimination of cross subsidies that tend to arise in regulated price structures, the incentives for cost minimizing behavior that result from the threat of entry, the incentives for innovation that competitive markets are thought to possess,[5] and the ability of small firms to meet the specialized needs of individual consumers.

The real question, however, is whether workable competition is attainable in an industry such as telecommunications. The argument takes two forms, both related to the rapidly changing technology in the industry. First, advances in both switching and transmission technologies have substantially eroded the traditional arguments for natural monopoly in telecommunications. Second, innovations in the potential uses of the communications network have made it impossible to draw a reasonable boundary between the wholesale service of transporting information and the retail service of providing or enhancing information. Rather than bear the inefficiencies associated with artificial regulatory boundaries, or alternatively, regulatory intervention into largely competitive markets, it is argued that completely unregulated markets would provide to best overall performance.

The factual basis of the first argument is clear. The implications of these changes in transmission and switching appear to work in different directions, however. Technical advances in transmission technologies have occurred at a steady pace for many years since the introduction of coaxial cable and microwave radio, and continuing through the development of fiber optic media. These innovations have lowered the average cost of transmitting a unit of information a given distance, but they have also increased the minimum efficient scale of transmission plant on any given route in the network. That is, innovations in fiber technology do not reduce the average cost of transmission on portions of the network that are optimally served by coaxial cable. As a result the minimum cost network tends to become more "tree-like" as cost reducing innovations in transmission technology proceed.[6] Of course, these tendencies may be counterbalanced in markets in which demand is growing over time. In any case it is true that economies of scale are exhausted on the most dense routes, since it would be prohibitively costly, even if it were feasible, to design a technology which could be fully utilized only on the largest capacity routes in the network.

Advances in digital technologies, and in particular in ISDN (Integrated Service Digital Networks), also have an ambiguous effect. Once a standard set of protocols exists in the public domain, it should be possible for more than one firm to cooperatively provide digital services. Until that time, the creation of ISDN simply raises the fixed costs of serving any collection of nodes.

In this case of switching technologies, the effect of the change is more clearly procompetitive. In any communications network, there is a tradeoff between switching and transmission that must be accounted for in a minimal cost design. Advances in digital technologies have reduced the cost of switching machines overall, and more importantly have made it possible to incorporate advanced technology features into switches of relatively small size. It is likely, therefore, that the network will evolve into one with more end office switches and shorter local loops, where the population density is sufficiently large.[7] When the number of local switches increases, the number of nodes in the overall network increases correspondingly. An increase in the number of nodes generates an exponential increase in the number of possible pairwise connections between nodes. Putting aside the possible economies of coordination and control, the innovations in switching technology appear to be unambiguously procompetitive.

Consider now the innovations in the use of the telecommunications network. Since current generations of telephone switching machines resemble digital computers, it is not surprising that the telecommunications network has the capability to manipulate information as well as to transmit it. The question is whether firms who transmit information should also be allowed to compete with other firms who provide so-called "information services" directly to consumers. The information services market is itself competitive, or more properly, monopolistically competitive by nature. Product differentiation and customized services are essential components of this market.

However, it is possible that transmission firms have a comparative disadvantage in some portions of the information services market due to economies of scope or to their own innovations. If transmission firms are regulated, and particularly if the transmission network is a natural monopoly under the control of a single regulated firm, there are certain to be undesirable incentives for the regulated firm to enter the competitive markets even in the absence of a cost advantage (Brennan, 1987). In a competitive telecommunications market, however, the transmission firms would have no such incentives; they would choose to enter related information markets if and only if there were a cost advantage. Thus, a competitive marketplace could reduce the costs of extensive regulatory accounting constraints whose only objective is to prevent cross subsidy, and at the same time allow firms to enter any markets in which they wish to compete.

I now turn to the arguments that might be made against competition, or competitive entry, into telecommunications markets. These arguments fall into three categories. Competitive markets may be inefficient. They may be unstable. Or they may lead to competitive outcomes that are considered unfair. I will consider each of these possibilities in the remainder of this section. Natural monopoly is the primary argument supporting claims that competitive equilibrium may be inefficient.[8] Natural monopoly in telecommunications may arise from scale economies in transmission, as has already been noted. More importantly, there are substantial economies of coordination that make it more efficient to plan and operate a large multiple link network more efficiently than would be possible with a collection of smaller networks. One example of such an efficiency is the possibility of alternative routing. When demand between two points varies over time, it is possible to overflow unusually large demands from a primary link to a secondary link which has unused capacity. Large networks have more alternative routes, so that a given probability distribution of point-to-point demand can be carried with less overall capacity on a large network than on two or more smaller networks.

Similar economies occur in the planning and expansion of network capacity. If demand is growing over time, it is possible to expand by relatively large increments on selected routes rather than by more frequent and smaller increments on all routes. Finally, a large network is able to take maximum advantage of the scale economies that exist in transmission, even if these are exhausted on the most densely used point-to-point links. For any set of three nodes for which point-to-point traffic exists, it can be shown that when demands are sufficiently small and fixed costs of transmission are positive, the two-link tree network is the minimum cost network. When competitive entry is possible on individual links in the network, it is possible that too many links will be constructed.

Closely related to the technical economies of scale and scope are the economies of coordination in network industries and the economies that result from the internationalization of network externalities (these issues are discussed by Carlton & Klamer, 1983, and Farrell & Solaner, 1986). The need for coordination occurs in virtually all technologically advanced industries. For example, in the computer industry, peripheral devices must be designed to work with each other and with a central processor, both physically through plug-in connections, and electronically with compatible software. In some, but not all cases, competitive markets can achieve a degree of coordination through leadership by a dominant firm, or a bandwagon effect when all firms agree on the same standard. When firms disagree about the proper standard and when technology is rapidly changing, coordination is less likely to be achieved.[9] In network industries, standards are particularly important. Railroads at one time operated on tracks of different gauge, necessitating the costly reloading of freight for shipments on more than one carrier. For a period of time, competitive pressures worked against the agreement on a common standard, as carriers sought to maximize their share of the total traffic (Chandler, 1977).

In telecommunications, protocols are just as necessary. The full establishment of ISDN requires worldwide cooperation of both users and carriers through the CCITT (Consultative Committee on International Telephony and Telegraphy). Because the technology of digital communications continues to evolve rapidly, there will be a need to continually evaluate the existing standards. At some point in the future after a standard has been accepted, it may be desirable to change the standard to take advantage of interim innovations. Even if all parties agree that such a change is worthwhile, however, there may be resistance to change since the benefits of changing a standard are only achieved if most or all parties act in unison. Since the cost to any one firm of organizing a common action may exceed its individual benefit, the old standard may prevail long after it is technically obsolete.

Another aspect of the need for coordination is strategic behavior of competing firms whose interests do not coincide.[10] An example is the sharing of revenue for telephone calls that cross jurisdictional boundaries. If there is one firm on each side of the boundary, the division of revenue can be determined through a bilateral bargaining process. However, once a formula is agreed upon , there may be inefficient incentives to relocate facilities or construct unnecessary new facilities in order to maximize a firm's share of the revenue. If a monopoly firm in one jurisdiction bargains with several competing firms in a different jurisdiction, the competing firms may be forced into a "prisoner's dilemma" in which the incentive to strike an independent bargain compels each to accept a minimal share of the joint revenue.

Closely related to the economies of coordination and standardization, are the economies which result from the internalization of network externalities. The benefit that an individual user obtains from joining a communications network depends on the number or other subscribers with whom he or she can communicate. If competing networks are not universally interconnected, then a new user will prefer to join a large network rather than a small one, although the primary incentive will be to join a network in which there is a community of interest. Firms that control large networks have a higher incentive to attract new subscribers, by charging lower access fees, because the benefits of increased communication possibilities are spread to a larger number of existing subscribers. Even if interconnection is costless, competing networks may refuse to interconnect in order to gain or enhance a competitive advantage.[11]

The second category of possible arguments against competitive telecommunications markets concerns the potential instability of the competitive process. The first, and most straightforward, context in which to describe unstable competition is to determine if something that resembles a traditional competitive equilibrium exists. It is not necessary that all of the technical conditions for existence of competitive equilibrium hold, since these are known to fail in the presence of indivisibilities associated with decreasing average costs. An alternative and more appropriate question is whether there exist "shadow prices," which would guide producers and consumers to reach optimal decisions in a decentralized manner. In the case of a simple triangular network in which scale economies are sufficiently great that only two of the three links are necessary, it can be shown that no such prices exist (Sharkey, 1990). Actual communications networks are much more complicated than the triangular example. However, the example demonstrates that if the minimal cost network is relatively sparse or tree-like, then prices by themselves cannot be relied upon to achieve the necessary coordination among competing firms and their customers.

A second possible source of instability in the competitive process may be examined from the perspective of cooperative game theory. The core of a game represents a set of outcomes that can be achieved by the set of all players, which no subset of players can object to. It is well known that the core contains the competitive equilibrium when the latter exists, but that the core exists in many cases in which there is no competitive equilibrium. The triangular network is one such example. Elsewhere (Granot & Huberman, 1981) it has been shown that core existence can be demonstrated in the class of all "spanning tree" games and some of their extensions. Even though it is possible to find examples of a communications network with a nonexistent core, from this point of view, competition appears to be quite workable.

A final context for determining competitive stability is based upon the properties of noncooperative competition. As noted in the introduction, section 3 is devoted to a study of these issues in some simple examples of competition in international networks. Several of the examples suggest the presence of unstable tendencies due to the nonexistence of pure strategy equilibria.

The final criterion with which to judge competitive markets is the issue of fairness. One unambiguous concept of fairness that has been suggested is that similar individuals should be treated similarly in the marketplace. For example, in a taxation setting, two people with similar incomes and similar characteristics should pay approximately the same taxes. By this standard competitive outcomes in telecommunications markets might have at least the appearance of unfairness, since competition cannot be expected to be equally effective on all parts of a complex network. Densely used routes will attract more firms than sparse routes. Therefore, customers on sparse routes might pay more than customers on dense routes, even if the average cost of production is the same. Furthermore, if competing firms control more than one link in a network, and there are overhead costs that must be recovered, competitive markets will tend to result in low prices on the routes where there is direct competition, and in higher prices on noncompetitive routes.

It is possible that competition on a portion of the network has spillover effects on other portions of the network. The results of section 3 indicate that spillovers exist, but that their effects may be unexpected. In one example, it is shown that increased competition on one link tends to raise the price set by a monopolist on another link, in equilibrium. In another example of a triangular network with competition on one link, there are no prices that constitute a pure strategy equilibrium for monopoly firms on the other two links. Compared to the equilibrium with monopoly on every link, profits of firms on every link fall, but customers do not obtain the full benefits of competitive pricing due to the mixed strategy equilibrium.

NONCOOPERATIVE EQUILIBRIUM IN SIMPLE INTERNATIONAL NETWORKS

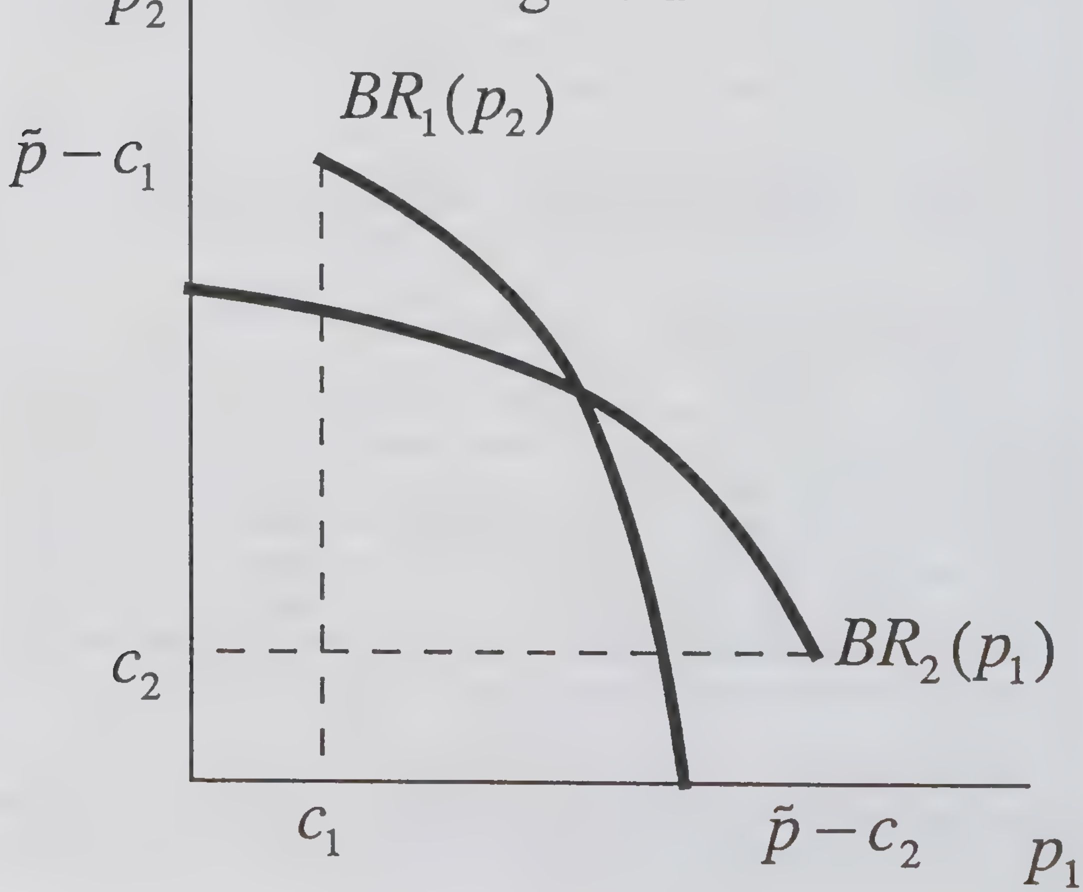
Competition on International Leased Line Networks

Because the global telecommunications network includes many separate political jurisdictions, the need may arise for two or more companies in separate jurisdictions or countries to cooperate in the provision of a particular service. International leased or private lines are a particular example. Multinational companies that wish to establish private networks linking branch offices in two or more countries must secure individual pieces of the network from a telecommunications provider in the country in which the given branch office is located.

This section will consider an example of the competition that exists among firms, in two countries, who must cooperatively supply a given service such as a private line network. First consider the case in which there is a single monopoly supplier in each country. It will be assumed that the international service offerings of each firm are unregulated, so that profit maximization is the sole objective of each firm.[12] The firms will be assumed to interact strategically in the choice of the prices p_1 and p_2 that are set in countries 1 and 2, respectively. Each firm will be assumed to have a constant returns to scale technology with constant marginal and average costs equal to c_i in country i. Let $Q(p) = Q(p_1 + p_2)$ represent the demand function for the international service. The profit function for supplier i, is therefore given by $II, (p_1, p_2) = (p_i - c_i)\ Q(p_1 + p_2)$. Assume that firms are able to choose any nonnegative price. For any price p_j in country j, country i has a profit maximizing "best response" price p_i, as a function of p_j. A Nash equilibrium of the resulting game consists of a pair of prices $(p^e_1, p^e_2$ such that p^e_i is a best response against p^e_j for $i \neq j$.

As long as the market demand function is reasonably well behaved, it is easy to see that a Nash equilibrium always exists in this example.[13] Suppose, for example, that the demand function crosses the vertical axis at $\tilde{p}$ and that the joint profit function $II(p) = (p - c_1 - c_2\ Q(p)$ is concave for $p = p_1 + p_2 \leq \tilde{p}$. It follows that the best response

Figure 1



functions are continuous and single valued, and that they necessarily intersect. A typical case is illustrated in Figure 1.

It is not necessarily true that there is a unique equilibrium. For example, the demand and cost functions of Figure 2a generate the reaction functions of Figure 2b for which a continuum of equilibria exist. These conditions might prevail in a market such as international teleconferencing, for there is potentially high value to a very limited number of users. The multiplicity of equilibria is a sign that the simple pricing model does not fully capture the dynamics of competition, since there is a source of conflict regarding the actual equilibrium to use. In a more complicated dynamic game this choice might be made through a bilateral bargaining procedure.

Each of the equilibria is inefficient, in the sense that total profits are less than the joint profit maximum. At any equilibrium point, differentiating the joint profit function and making use of the first

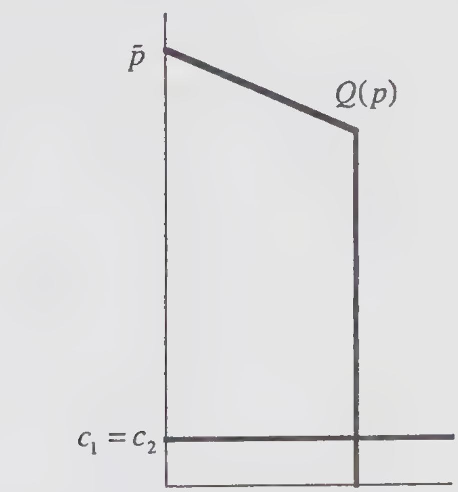


Figure 2a

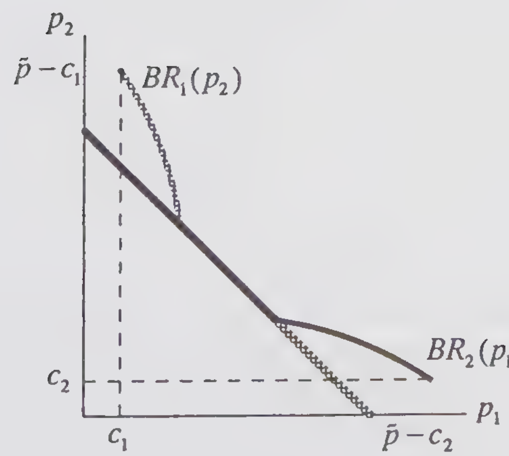


Figure 2b

order conditions which must hold at an equilibrium point leads to the result

$$\frac{\partial(\Pi_1(p_e) + \Pi_2(p^e))}{\partial p_i} = Q(p^e_1 + p^e_2) + (p^e_1 + p^e_2 - c_1 - c_2)Q'(p^e_1 + p^e_2)$$
$$= (p^e_j - c_j)Q'(p^e_1 + p^e_2) < 0.$$

That is, both firms should reduce prices from their equilibrium values in the interests of joint maximization. Of course, any joint maximizing prices (p_1^*, p_2^*) are not equilibrium prices. Neither firm is willing to take account of the additional profits that accrue to the other firm following a price reduction.

Suppose now that competition is allowed in one of the countries. As long as average costs are constant and firms compete only by choosing prices, the number of competitors in the competitive country does not matter, if there are two or more. Thus, suppose that firm 1 represents the monopoly supplier in one country and that firms 2 and 3 represent the competitive suppliers in the other country. All firms compete by choosing prices and the low price supplier in the competitive country will be assumed to serve the entire market. In the event that both competitive suppliers choose the same price, they evenly divide the market. Profit functions are then given by

$$\Pi_1(p_1,p_2,p_3) = (p_1 - c_1)Q(p_1 + Min\{p_2,p_3\})$$

$$\Pi_i(p_1,p_2,p_3) = \begin{cases} 0 & \text{if } p_j < p_i \\ (p_i - c_i)Q(p_1 + p_i) & \text{if } p_i < p_j \\ (p_i - c_i)Q(p_1 + p_i)/2 & \text{if } p_i = p_j \end{cases}$$

Firms in the competitive country behave as ordinary competitors in a Bertrand pricing game. If marginal costs in the competitive country are equal, $c_2 = c_3 = c$, then with suitable restrictions on the demand function, a unique pure strategy equilibrium is given by $p^e_2 = p^e_3 = c$ and

$$p^e_1 = c_1 - \frac{Q(p^e_1 + c)}{Q'(p^e_1 + c)} \quad .$$

It is possible that the equilibrium price in the monopoly country either rises or falls with the introduction of competition in the other country. The result depends on the particular demand function. With linear demand functions, the supplier in one country always raises price in response to a reduction in the price set by the other country. In this case the price reduction brought about by competition is partially offset by a price increase in the monopoly country.

Competition in International Switched Service Markets

International switched services present another set of issues regarding coordination and competition between telecommunications suppliers in different countries. In contrast to private line offerings, which make use of dedicated facilities, switched services can be purchased by any subscriber in the home country and transmitted virtually anywhere in the world. The costs of carrying a given message are therefore shared by at least two suppliers in different countries. The revenue from an international message, however, is collected entirely by the supplier in the originating country. As a result, a set of institutional arrangements have arisen to compensate a supplier in one country for message transmissions which originate and are billed in another country. While the actual arrangements are complex, they involve, in essence, a negotiated accounting rate which is used to compensate the destination country for the costs which it incurs. This rate, which differs from the tariffed rate in either country, is applied to the difference between incoming and outgoing minutes of use during a given time period (Eward, 1985, p. 399).

This practice has led to concern over possible abuses that might arise when competitive entry occurs in one country, but not in the other. Depending upon whether the monopoly country was a net originator or receiver of a particular kind of service, the supplier in that country would have the incentive to set either a low or a high accounting rate. If there were several competing suppliers in the other country, it would be possible for the monopoly country to effectively impose its desired rate by selectively directing services to the competitive supplier offering the most favorable terms. This practice has been described as *whipsawing*. The straightforward remedy for this potential abuse is for the government in the competitive country to act as the agent of the suppliers in the negotiation of the accounting rate. It will be assumed that the government in the competitive country accepts this responsibility.

Taking these institutional assumptions as a starting point, this section will describe the nature of the outcomes which can be expected when firms in two countries interact in the choice of prices for an international switched service. Initially, assume that there is only one supplier in each country. Let $Q_i(p_i)$ represent the demand function for traffic which originates and is billed in country i. Let p^a represent the negotiated accounting price, which is assumed to be determined independently of the setting of prices in either country. As in the previous section, it will be assumed that marginal and average costs are constant and equal to c_i in country i.

Profit functions are therefore given by

$$\Pi_i(p_1, p_2) = p_i\, Q_i\,(p_i) - c_i\,[Q_1(p_1) + Q_2(p_2)] - p^a[Q_i(p_i) - Q_j(p_j)]$$
$$= (p^a - c_i)\, Q_j(p_j) + (p_i - c_i - p^a)\, Q_i(p_i)$$

From the second equation in the profit function, it is clear that, while profits depend upon prices in each country, there is no room for meaningful strategic interaction. Each supplier has a dominating strategy that consists of setting price equal to the price p_i^e which maximizes $(p_i - c_i - p^a)\, Q_i(p_i)$, assuming that demand functions are such that a maximum exists. This strategy is a best response to any price p_j that might be set by the other country. Thus, each firm sets a price, which would be a profit maximizing price if the true marginal costs were $c_i + p^a$. If marginal costs are equal in each country and the accounting price is set equal to this common value, the equilibrium prices also maximize the joint profits. If the accounting rate exceeds the marginal cost of both suppliers, then, as in the previous section, the partial derivatives of the joint profit function are negative at the equilibrium prices, and so a price reduction by each supplier would be mutually beneficial.

The introduction of competition in one country does not change the equilibrium price chosen in the monopoly country, since p_i^e was shown to be a dominating strategy. If country 1 is the monopoly country, and two or more firms in country 2 compete as Bertrand competitors, with identical marginal costs, it is easily demonstrated that the unique equilibrium price in the competitive country is given by

$$p^e_1 = c_1 + p^a - \frac{(p^a - c_i)q_1(p^e_1)}{Q_2(p^e_2)}$$

If $p^a > c_i$ then necessarily $p^e_2 < c_i + p^a$. If in addition Q_2 is small relative to Q_1 it is possible that $p^e_2 < c_i$.

Competition in a Market with Fixed Costs*

One aspect of competition in a network industry is the possibility of entry into new markets by firms who are established in other markets. An example is the airline industry, as planes can be easily switched from one city pair route to another. This form of competition has been described as *hit-and-run entry,* and it has been argued that, under some conditions, the potential competition of this form is

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* This section, and the following one, describe in summary form results that appear elsewhere (Sharkey, 1987).

sufficient to lead to "competitive" outcomes even if there is room for only one active carrier on a given route (Baumol, Panzer, & Willig, 1982). Markets in which hit-and-run entry is possible are known as *perfectly contestable markets*.

Most telecommunications markets do not satisfy the contestability conditions due to the required investments in right of way, which are required for terrestrial transmission facilities. International telecommunications markets, however, may satisfy the contestability conditions. Transmission by satellite makes it possible for a carrier to switch instantly from one route to another, as long as there is sufficient capacity. Another example is the potential competition between international record carriers and voice carriers. At one time the technologies of hard copy transmission and voice transmission were sufficiently different that each kind of carrier was restricted to its own market. Newer technologies, such as packet-switching networks, are being adopted by both kinds of carrier. Thus, the same facilities can be used to enter each other's markets.

This section will consider a model of hit-and-run entry when there are positive, but possibly small, fixed costs associated with entry. These may be due to the need to advertise a firm's intention to compete. The fixed costs may also be due to foregone profits in an alternative market that must be temporarily abandoned in order to compete in a new market. Production may require physical plant, which embodies large fixed costs that are "sunk" costs only to the extent that the capital is unavailable for other uses. The degree to which the fixed costs are sunk costs is therefore related to the length of the period during which a commitment is necessary in order to effectively compete in a given market. This time interval may depend on the responsiveness of consumers, the complexity of the product or service, and so on. In any case, the interpretation will be that a fixed cost equal to f must be incurred if a firm chooses to compete, but can be avoided if the firm chooses not to compete. There will be two firms who can potentially serve a given market. If either or both of the firms choose to enter the market, competition will be in terms of prices. If both firms are in the market at the same time, then the firm quoting the lowest price serves the entire market, and the firm that loses the market pays the fixed cost but does not receive any revenue. In the event of a tie, it will initially be assumed that both firms share the market equally.

In order to represent the market as a game, it is necessary to describe the exact sequence of moves, and the payoffs to each player at the end of every possible sequence. It is also necessary to specify the information available to each player at each point at which a decision or move must be made. There are two possible representations, depending upon the information that is available to each player at the time a pricing decision must be made. In each case the two players simultaneously choose whether or not to enter the market, not knowing the choice of the other player. Then the player or players in the market choose a price, without knowing the choice of the rival player. The game forms differ only in whether or not each player can observe the entry decision by the rival before choosing a price.

Suppose first that the entry decision is observed before prices are chosen. This game is easily solved by a backward induction argument.[14] If both firms decide to enter the market, they will compete in prices according to the standard model of Betrand price competition. Prices are forced down to marginal cost, and the net profit of each firm is equal to $-f$. If only one firm is in the market, it is free to choose the monopoly price, p^m, knowing that the other firm has already chosen not to enter. If neither firm chooses to enter, they both earn net profit equal to 0. It is easily demonstrated that there are two pure strategy equilibria corresponding to the entry by exactly one firm. In both cases, price in the market remains at the monopoly price. This result holds for any value of fixed cost $f > 0$. Therefore, potential competition, or hit and run entry, is of no value in disciplining a market which is accurately described by this game form.

It is interesting to observe that for this game, a regulated minimum price would improve market performance. Suppose that neither firm is allowed to charge a price less than p^{min} in the second stage game after entry decisions have been made. Then if both firms choose to enter, the unique equilibrium requires both firms to choose p^{min}. If net profits of each firm at p^{min} are greater than zero, then p^{min} is the unique equilibrium strategy for the entire game. If p^{min} is sufficiently small, profits of each firm will be close to zero in this equilibrium, and the market price will close to the minimum possible price.

The more interesting case is the one in which firms must make a decision to enter or not, and then choose a price if entry was chosen, all without observing any of the decisions of the rival firm. In this game, it is convenient to use a different tie-breaking rule in the event of equal prices. Suppose that one firm, designated the "incumbent," serves the entire market in this case.[15] The strategy sets for each player consist of the sets $S_1 = \{out, p_i\}$ where p_i represents the strategy "enter the market and choose price p_i."

It is easy to see that a pure strategy equilibrium does not exist for this game. If both firms choose to not enter the market, then both would like to enter at the monopoly price p^m. If both firms choose to enter the market, then the high price firm, or the nonincumbent in case of a tie, would prefer to to choose {*out*} or to choose a lower price. If only one firm chooses to enter at a price $p_i < p^m$ that firm would prefer to raise its price to p^m. If there is one firm in the market charging a monopoly price, the outside firm would prefer to enter at a slightly lower price.

The nonexistence of a pure strategy equilibrium indicates that neither firm is able to choose an equilibrium price, taking any particular price of the rival firm as given. Thus there is a fundamental uncertainty on the part of each firm about the exact price that will be chosen by the rival firm in equilibrium. This uncertainty is described by a mixed strategy equilibrium, which specifies a probability distribution of strategies for each firm. As in a pure strategy equilibrium, neither firm would wish to alter its probability distribution, given the equilibrium probability distribution of the rival.

In this example there are two mixed strategy equilibria. In the asymmetric equilibrium, firm 1, the incumbent, always chooses to enter the market and chooses a price in the interval $[p^f, p^m]$. p^f represents the zero profit price, net of fixed costs, and p^m represents the monopoly price. Firm 1 chooses the monopoly price with positive probability, which depends on the size of the fixed costs *f*. For all prices less than p^m the probability distribution function $F_1(p)$ is continuous, so that there are no mass points. In equilibrium, firm 2, the rival, chooses to stay out of the market with positive probability (equal to the probability that firm 1 chooses p^m) and to choose prices from the

This example is consistent with the assumptions necessary for a perfectly contestable market, except for the existence of a positive fixed cost *f*. If *f* is small, the probability that the incumbent firm chooses the monopoly price, and the probability that the rival firm chooses to stay outside of the market is also small. Similarly the cumulative distribution functions $F_1(p)$ and $F_2(p)$ converge to the pure strategy choices $p_1 = p_2 = p^f$, as *f* approaches zero. In this way the equilibrium in this model confirms the prediction of the contestable market hypothesis, which is that potential entry is sufficient to force the market price to the zero profit point. However, if fixed costs are founded away from zero, the zero profit p^f is never chosen with positive probability by either firm, and although both firms continue to earn zero expected profits, any price up to and including the monopoly price can be expected in the market.

Figure 3 illustrates the probability distribution functions for the incumbent player, with various values of fixed costs, and a market characterized by a linear demand function and constant marginal cost

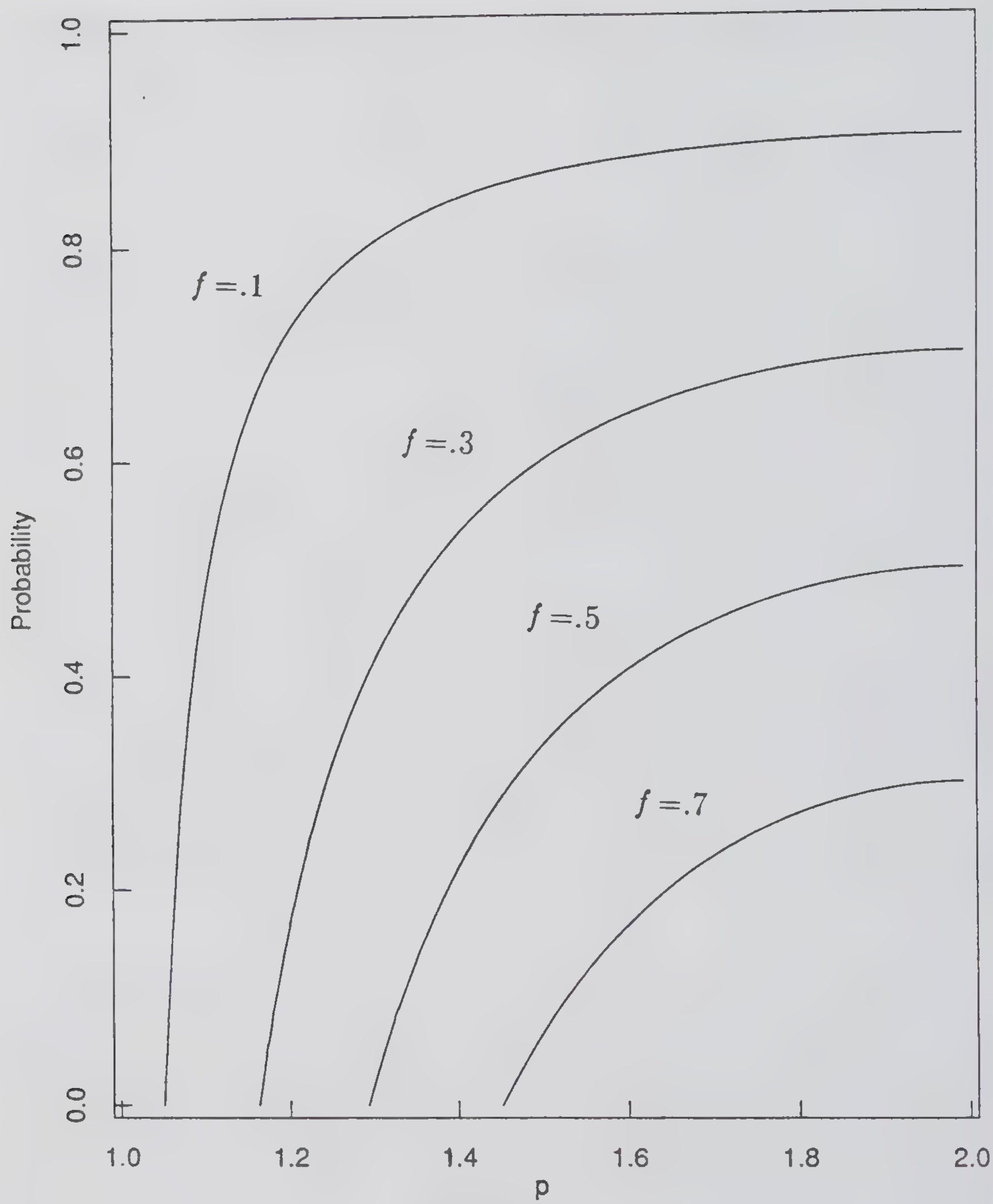

Figure 3

of production equal to 1. In this market, maximum profits equal to 1 are attained at a price of 2. The zero profit price p^f depends on the size of the fixed costs f. For all prices p between p^f and 2, the probability, $F_I(p)$ that the nonincumbent chooses a price less than or equal to p is shown. The function F_I is discontinuous at $p = 2$, and the size of this discontinuity represents the probability that the incumbent chooses the monopoly price (and also the probability that the non-incumbent chooses to not enter the market). Thus, for small fixed costs, the probability of choosing a price far from their zero profit price is small.

For large fixed costs, the probability that the incumbent chooses the monopoly price, and the probability that the nonincumbent chooses to not enter, becomes large. This equilibrium therefore resembles the equilibria in the two-stage game analyzed previously. It is also true, in this example, that the conditional probabilities of choosing a price less than or equal to p, given that entry occurs and that the monopoly price is not chosen, are the same for both players.

In the case of moderate to large fixed costs, both equilibria also have a disturbing property, that is characteristic of some but not all, mixed strategy equilibria. In equilibrium, the incumbent firm and the nonincumbent firm both expect to receive zero profits, on average, if the other firm uses its equilibrium strategy. However, both firms could earn zero profits with certainty by choosing a certain pure strategy, even if the other firm does not use its equilibrium strategy. The incumbent can do so by choosing $p_1 = p^f$, and both can do so by choosing to remain out of the market. These strategies are clearly not in equilibrium. The incumbent would prefer to charge any price $p_1 > p^f$. However, if the incumbent behaves as a Stackleberg leader, then it is possible to choose a mixed strategy that will earn positive profits, and for which the best response of the non-incumbent is to remain outside of the market. Any mixed strategy F for which $F(p) > F_1(p)$ for all $p \in [p^f, p^m]$ will have this property. There is no comparable leadership advantage for the nonincumbent. Therefore, it is plausible to argue that the incumbent can earn positive profits by acting as a mixed strategy Stackleberg leader.

The implications of the two models described in this section are straightforward. When firms compete in a single market using prices and entry decision as strategic variables, the outcomes depend critically on the timing of moves and the magnitude of the fixed costs that can be avoided by choosing not to compete. If the entry decision can be observed before prices are chosen, then the only (subgame perfect) equilibria consist of one firm choosing to enter the market at a monopoly price, and the other firm choosing not to compete. If the entry decision the pricing decision are made simultaneously, then there is a unique equilibrium, and the outcome is more competitive. If fixed costs are small then this equilibrium may be indistinguishable from the contestable market prediction. However, if fixed costs are large, the market equilibrium is less satisfactory. Although both firms earn zero profits in equilibrium, the equilibrium depends on mixed strategies on the part of both players. Prices higher than minimum average cost are set in every realization of the probabilistic mixed strategy. In this example, there is an additional problem due to the slight asymmetry involving the definition of incumbency. The safe strategies do just as well for each firm as the equilibrium strategies, but the incumbent can earn positive profits by acting as a Stackleberg leader.

Competition Between Foreign and Domestic Suppliers

The previous section considered the equilibria in a market in which a prospective entrant was required to bear a fixed cost before competing. This section will also consider competition between suppliers in different markets. However, instead of a fixed cost, it will be assumed that each market is supplied by a constant marginal cost technology. The suppliers in each market supply an output or service that is identical in every respect, except for location or other characteristic that defines the market. It will be possible for a supplier in one market to compete for customers in another market, but each supplier will be assumed to have an advantage in its own market. This advantage will take the form of a cost differential on each unit of output that is sold.

There are a number of cases in which this form of competition is reasonable. One obvious example, which has received some attention in the literature, is spatial competition.[17] When two firms supply a product for which transportation costs must be incurred in reaching final consumers, location is an important competitive advantage. Every firm can compete for the customers of every other firm, but each firm has a local monopoly due to the lower cost of supplying nearby customers. If products are differentiated in quality or attribute, the spatial model is also appropriate, since firms must choose a location in characteristics space.

In the telecommunications industry there are other examples of potential competition across market boundaries. A communications network generally has many different possible paths linking a given pair of points. If individual links in the network are owned by different suppliers, it is possible for two firms to compete for the same point to point traffic. Each carrier will have an advantage in serving some of the point to point markets. Consider a triangular network linking three different countries, or within a country with each link owned by a different supplier. Suppose that one link is highly competitive, while the other two are controlled by a single supplier. Each of the monopoly suppliers is able to compete for the other link's traffic by using the competitive link as a partner. However, there is a symmetric cost advantage for each carrier in its own market if the cost of using the competitive link is greater than zero.

In addition to the literal locational or network examples, there are more general instances of cross market competition in the telecommunications industry. Technology which is well suited to one kind of communications traffic may be adaptable, at a reasonable cost, to a different kind of traffic. International record carriers and international voice carriers might compete in this manner. New information-processing technologies such as videotext are also examples of this form of competition. While similar in technology, different kinds of data services require specialized knowledge of the market, which confers a cost advantage on the primary supplier.

This section will investigate the equilibria in a model in which two firms in different markets compete in the above manner. It will be assumed that the firms have constant marginal cost technologies. Each firm can compete for customers in the other market but there is a cost penalty of $c > 0$ for each unit sold outside the firm's own market. Competition is in terms of prices. The supplier quoting the lowest price, including the penalty c, supplies the entire output in either market. In the event of a tie, that is, $p_i = p_j + c$, it will be assumed that each firm serves only its own market.

In this example, there may exist a pure strategy equilibrium, if the cost advantage is sufficiently large. A pure strategy equilibrium can exist only if each supplier serves its own market, and at least one of the suppliers charges a monopoly price. Each firm can guarantee positive profits by choosing a price equal to c. Thus, no firm will allow its rival to undercut its price in equilibrium. But if (p^e_1, p^e_2) is an equilibrium pair, the low-price firm will always prefer to raise its price a small amount, unless it is already at the monopoly price. Therefore, if a pure strategy, equilibirum exists, it is unique and can be characterized by prices (p^e_1, p^e_2) such that firm i sets a monopoly price, $p^e_i = p_i^m$, and $p^e_i < p^e_j < p^e_i + c$. The low-price firm sets a monopoly price. The other firm sets a price at which neither firm wishes to capture the other market. If the cost advantage c is large, then it is more likely that both firms will set a monopoly price.

If c is sufficiently small, but positive, then no pure strategy equilibrium can exist. Since $|p^e_j - p^e_i| < c$ at any candidate for equilibrium, it follows that at least one firm would prefer to reduce its price and capture both markets. Whenever a pure strategy equilibrium fails to exist, there is a unique mixed strategy equilibrium. This equilibrium has a particularly simple and intuitive form. Firm i chooses prices from an interval $[p^l_i, p^h_i]$. It can be demonstrated that $p^h_i - p^l_i \leq 2c$ and that $p^h_i - p^l_i < 2c$ only if $p^h_i = p^m_i$. Furthermore, $p^l_i \leq p^l_j + c \leq p^h_i$. At a mixed strategy equilibrium, each player receives the same expected payoff at each of the prices that could be used in equilibrium, given the equilibrium distribution of prices of the opposing player. Therefore, the distribution functions $F_i(p_i)$ and $F_j(p_j)$ must be chosen to equalize the expected profit of the opposing player over the relevant interval. If firm i chooses the price $p^l_j + c$ it is certain that neither player will underprice the other, given the above inequalities. Therefore, the expected profit of player i is positive and is equal to the profit of serving the home market at the price $p_j^l + c$.

If market i is strictly larger than market j then $p_i^l > p_j^l$. If market i grows in size, so that the profit function II_{ii} shifts up at every price, p_i^l unambiguously increases. p_j^l may either increase or decrease, but it is certain that the profits of firm j increase.

These results suggest that a small country can be a more effective competitor to a large foreign supplier than a country of comparable size, assuming that suppliers in each country are freely allowed to enter each other's territory. The reason is that small markets allow only small profits in equilibrium. The firm in the larger market must therefore charge prices that are sufficiently low that entry is unattractive. These results hold for both pure and mixed strategy equilibria. If the markets in two countries are comparable in size, firms in each market earn higher expected profits than in the asymmetric case. Of course the price interval in the mixed strategy equilibrium must be chosen low enough relative to c, so that undercutting of prices is not a profitable activity.

CONCLUSIONS

The objective of this chapter has been to describe the nature of competition in markets like telecommunications which have been traditionally organized as regulated monopolies or public enterprises. In the largely nontechnical section 2, a broad survey of known results was attempted. One of the implications of that survey is that relatively little is actually known about the kind of outcomes that can be expected as more and more countries allow competitive entry into certain telecommunications markets. These markets are by no means perfectly competitive, but they may not be natural monopolies either, in most countries, due to changing technologies and overall growth in the markets.

Section 3 represents an attempt to describe the oligopolistic equilibria that can be predicted in simple markets, which have some of the characteristics of actual telecommunications markets. Sections 3.1 and 3.2 were concerned with inefficiencies in international competition for leased line and switched service markets. In the private line market, these inefficiencies are inevitable, unless there are binding agreements not to use equilibrium pricing strategies, due to the failure to coordinate pricing decisions. In switched service markets, the inefficiency arises only if the negotiated accounting rate is set at too high a level above marginal costs. It was pointed out, however, that a country with a large net inflow of traffic has an incentive to bargain for a high accounting rate.

Sections 3.3 and 3.4 were concerned primarily with the mixed-strategy equilibria that arise when firms in one market compete with firms in another market. Mixed-strategy equilibria arise when there is either a fixed cost of entry or a cost advantage of serving the home market. As these costs go to zero, the equilibria in both cases converge to the pure strategy, zero profit, Betrand equilibria. If it is reasonable to suppose that the costs are significant, one should expect that competition of this type would be fundamentally unstable. The instability or unpredictability of competitive outcomes is not necessarily a bad thing. One must examine the alternatives. If the alternatives are monopoly conditions in each market, then competition unambiguously lowers prices and enhances consumer welfare. If the alternatives are regulated or state-owned monopoly, then no definite conclusions can be drawn at this level of generality. Even though the profits of firms are limited by competition, the mixed-strategy equilibria involve the use of prices higher than would be necessary to attain these profit levels. In the fixed cost example all prices up to the monopoly price can be chosen by either firm. In the example of the cost advantage, the prices are confined to a definite interval, whose size depends on the size of the advantage.

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ENDNOTES

[1] U.S. vs AT&T, U.S. District Court for the District of Columbia, Civil Action No. 74–1698.

[2] The divestiture of AT&T resulted in the creation of seven regional companies to own and manage the 22 former Bell Operating Companies. The territory of each operating company was divided into one or more Local Access and Transport Areas (LATAs), which defined the boundaries between local communications and long distance communications. At the time of divestiture, it was thought that inter-LATA toll markets would be open to competition between AT&T and new entrants, while intra-LATA toll and local access would remain regulated monopolies. Since the divestiture, some states have allowed competition in intra-LATA toll. There has also been competition in local access markets, particularly from large users.

[3] In the United States, the first patent for the telephone was granted to Alexander Graham Bell on March 3, 1876. In 1893, when the Bell patents expired, the industry was opened to competition at the local level, although the Bell companies retained a monopoly in long distance communications. Before the Communications Act of 1934 established the era of regulated monopoly, AT&T had the potential to enter markets outside of the traditional telephone industry, such as radio broadcasting and sound motion pictures.

[4] There was successful entry into the markets for terminal equipment even earlier. Today equipment markets seems to be highly competitive. However, this chapter will not be specifically concerned with equipment manufacturing or retailing.

[5] Both the theoretical and empirical support for this point are ambiguous, however.

[6] The minimal cost network is a (spanning) tree if there is only one possible path between every pair of nodes. If all of the costs involved in transporting messages were fixed costs, then the minimum cost network is necessarily a tree.

[7] This argument is made by Huber (1987). Since the local loop does not make use of shared capacity to a significant extent, there are relatively few innovations in transmission which are likely to counterbalance the reductions in switching costs.

[8] Whether or not the telecommunications network in any given country is a natural monopoly is an empirical question. In any case, for obvious political reasons, the worldwide network cannot usefully be considered a natural monopoly. The intention of this chapter will be to disregard the traditional arguments for natural monopoly in network industries, so as to focus more closely on the properties of competitive markets. Therefore, the case for natural monopoly will only be sketched at this point.

[9] The competing formats in videocassette recorders is an example.

[10] Section 3 contains several examples of strategic interaction on simple networks. In most of the examples, the noncooperative equilibrium is inefficient to the firms or their customers, and in some cases both.

[11] In the early years of this century, competing local telephone companies in the United States typically refused to interconnect, and AT&T for a time refused to provide long distance service to nonaffiliated companies. Brock (1981) documents the growth of the industry from the invention of the telephone up to the time of the divestiture of AT&T.

[12] The firms need not pursue profit maximization as an overall objective. However, if there is a budget constraint, or a welfare objective other than profit maximization overall, it is assumed that profits from the international market are sought in order to subsidize domestic markets.

[13] In this example there always exists an equilibrium in "pure strategies" as defined above. In some of the examples to be considered later, pure strategy equilibria do not exist. However, there will always exist at least one equilibrium in "mixed strategies" in which players are allowed to choose a probability mixture of the pure strategy choices and payoffs are in terms of expected profits.

[14] Equilibria which can be solved in this way are known as *subgame perfect* equilibria.

[15] This assumption is natural for telecommunications markets that were at one time served by regulated or public monopolies, which are later challenged by potential entrants. It will be shown that, in equilibrium, ties cannot occur with positive probability. Every equilibrium of the asymmetric game can also be shown to be an equilibrium of the symmetric game in which the market is shared equally when prices are equal. In the latter game there there is one additional equilibrium.

[16] There is also a symmetric equilibrium in which both firms use the equilibrium strategy of the rival firm. In a symmetric version of the example, with no advantage of incumbency, there are two asymmetric and one symmetric equilibria.

[17] The original contribution is due to Hotelling (1929). d'Aspremont, Gabszewicz, and Thisse (1979) pointed out an error in Hotelling's analysis and observed that a pure strategy equilibrium need not exist in a model of spatial competition. Gal-Or (1982) computed the mixed-strategy equilibria in the standard Hotelling model. This section generalizes these results to essentially arbitrary demand functions.