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Intellectual Property, Antitrust, and Strategic Behavior

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Executive Summary

Economic growth depends in large part on technological change. Laws governing intellectual property rights protect inventors from competition in order to create incentives for them to innovate. Antitrust laws constrain how a monopolist can act in order to maintain its monopoly in an attempt to foster competition. There is a fundamental tension between these two different types of laws. Attempts to adapt static antitrust analysis to a setting of dynamic R&D competition through the use of "innovation markets" are likely to lead to error. Applying standard antitrust doctrines such as tying and exclusivity to R&D settings is likely to be complicated. Only detailed study of the industry of concern has the possibility of uncovering reliable relationships between innovation and industry behavior. One important form of competition, especially in certain network industries, is between open and closed systems. We present an example to illustrate how there is a tendency for systems to close even though an open system is socially more desirable. Rather than trying to use the antitrust laws to attack the maintenance of closed systems, an alternative approach would be to use intellectual property laws and regulations to promote open systems and the standard-setting organizations that they require. Optimal policy toward R&D requires coordination between the antitrust and intellectual property laws.

I. Introduction

Over the past twenty years macroeconomists have given renewed attention to the importance of technological change for economic growth. Since Schumpeter, microeconomists have understood that there may be a trade-off between achieving static efficiency through competition and achieving long-run efficiency through optimal investment in research, development, and diffusion of innovation. Recent empirical research in industrial organization demonstrates that the social value generated by new goods is large. This suggests that policies that encourage innovation, even perhaps at the expense of short-run market power, may be beneficial.

The traditional roles of antitrust policy and industry regulation have been to promote static efficiency. Acknowledgement of the importance of technological change, therefore, raises several important questions for antitrust policy.[1] The questions relate to whether and how antitrust policy should concern itself with promoting efficient dynamic competition in technological change, whether and how the static concerns of traditional antitrust policy should apply in industries with rapid technological change, and to what extent courts are capable of dealing with the complexities and uncertainties of technological competition.[2]

In this chapter, we explore several aspects of these questions. First, we consider merger policy, one of the most important areas of antitrust enforcement. One argument that has been put forth is that antitrust authorities should consider "innovation markets" separately from standard product markets and block mergers that significantly increase concentration in such an R&D market. We explain how three conditions are necessary to justify such an expansion of traditional concerns in mergers. They are: (1) reducing R&D expenditures is undesirable; (2) if there are fewer firms performing R&D, there will be less aggregate R&D and fewer new products; and (3) it is possible to determine that there are not enough other firms to perform R&D and develop future products to compete with the future products developed by the merged firm. We argue that there is no general theoretical or empirical support for any of these three conditions. Therefore, we are skeptical of the benefits of expanding antitrust merger enforcement to block mergers that concentrate "innovation markets" as a general policy, with the important caveat that there may be several special industries where such a policy may be sensible. Moreover, in some cases certain types of evidence, which we discuss below, may be available that could justify blocking a merger.

Intellectual property (IP) policy (patents, copyrights, trademarks, trade secrets) conveys market power to developers of IP. Antitrust policy determines, in large part, the constraints society places on companies with extensive market power. This creates a potential fundamental conflict between IP policy and antitrust policy. IP policy conveys market power; antitrust policy constrains its use. Therefore, any application of antitrust policy in R&D-intensive industries should consider whether it is complementing or thwarting the goals of IP policy. If under current antitrust enforcement, IP policy generates the amount of market power that creates the optimal incentives for R&D, then any significant change in antitrust policy towards R&D-intensive industries could lead to suboptimal R&D investment. At a theoretical level, the right question is "is it a good idea to change antitrust enforcement and simultaneously alter IP protection to keep R&D incentives the same?" But this is a policy adjustment beyond the powers of either antitrust authorities or the courts.

IP policy and other features of high-tech industries such as network externalities and economies of scale in R&D make the existence of short-run market power common. The legal doctrines and economic analysis that underlie antitrust policy have largely developed without a focus on dynamic technological competition. Because of the prevalence of market power in high-tech industries, it is important to understand the fit between existing policy and the features of these industries. The proper application of antitrust doctrines such as predation, tying, and exclusive contracts to high-tech industries is an issue of significant importance. These issues have received a fair amount of theoretical attention, so we touch on them briefly and only make some general observations. We argue that many of the theories that justify these antitrust doctrines also apply in high-technology companies, but several additional caveats may apply. First, the factual inquiry may be much more difficult, requiring courts to make complex and subtle judgments about disputed technology issues. This makes the process more costly and more prone to errors. Second, developing workable rules that provide guidance to companies with market power may be very difficult.

We also explore the role for antitrust enforcement to affect dynamic R&D competition that attempts to replace existing market leaders. In many high-tech industries, competition is inherently dynamic. A single technology may be the winner in the marketplace at one point in time. Competitive forces will then be focused on developing new technology that can replace the existing winner. Antitrust policy towards companies with market power did not develop with this form of competition in mind. The proper role for antitrust policy in making this process work effectively has received little attention, but may well be the most important way that antitrust policy can affect competition in high-tech industries. We consider this question in the context of dynamic, multigenerational platform competition, where participants can choose between developing closed and open systems. We argue that winners in early stages of competition often have the incentive and ability to close the system and thereby reduce subsequent competition.

We provide some preliminary thoughts on the role for antitrust policy to improve this dynamic systems competition. We do not attempt to develop any standards that enforcement agencies or courts should adopt, but we do think our theoretical arguments imply that close attention should be paid to conduct that creates a proprietary, closed system subsequent to open competition. However, policies other than antitrust enforcement may be more effective instruments to improve performance. Government subsidization of standards development, reduced restrictions on research joint ventures, or other forms of research coordination where systems are important may be justified. Furthermore, companies that subvert cooperative standard-setting processes to create their own proprietary, closed systems should face severe penalties.

The remainder of the chapter is organized as follows. Section II outlines the essential features of R&D competition that form the basis for our subsequent analysis. Section III discusses the role of antitrust enforcement for mergers in R&D-intensive industries. Section IV discusses the scope of monopolization issues in R&D-intensive industries. In section V we discuss multigenerational competition among open and closed systems and discuss its implications for antitrust and other policy. Section VI concludes.

II. Characteristics of R&D Competition for Antitrust Policy

Perhaps the most important single characteristic of technology competition is uncertainty. Not only is the outcome of any particular R&D project uncertain, but so is the impact of successful innovation on markets and competition. Anecdotes abound of an industry being transformed by an innovation coming from completely unrelated industries, bringing in completely new technology.[3] These anecdotes show that basic research can have unanticipated consequences, and perhaps more importantly, that the same is true even for very applied, specific research. However, it is possible to make too much of these anecdotes. We discuss below a growing body of systematic empirical evidence that much innovation in an industry comes from within it. We note, however, that these studies define industries broadly relative to the typical market definition used for antitrust enforcement.

All policy towards technological competition should take into account the inability to foresee perfectly the outcome or impact of R&D. The structure of the patent system can be best explained by the inability of government officials to foresee the influence of particular technologies on R&D activities. The outputs of R&D are ideas. Once an idea is discovered, the marginal cost to society of using the idea is close to zero. Without property rights over ideas, good new ideas would be freely employed. Although efficient after the fact, the result may be no return for the innovator, reducing the incentive to engage in innovative activity. Patents convey monopoly power to innovators, who then can charge supercompetitive prices for goods that embody the patented technology and/or license the technology at a price above the marginal cost of transfer.

If government officials were omniscient, a superior system would be to subsidize R&D directly or award prizes to innovators based on the value of the innovation. This would create incentives to engage in innovative activity and avoid the monopoly distortions of the patent system. Although we do provide significant subsidies for R&D projects, this approach is limited by the enormous difficulty of determining the appropriate size of prizes or direct subsidies to specific projects.[4] Policy instead is a mixture of subsidies (usually to basic research by nonprofit institutions), patents, and other forms of property rights.[5]

A characteristic of technology competition closely related to uncertainty is its dynamic nature. Not only does the process of R&D take time, but also the goal of technological competition is to replace existing technology with new technology, an inherently dynamic process. All policy toward technological competition should acknowledge this. Policy based on static models of competition must be evaluated with great care before applying them to technological competition.

High concentration and short-run market power in the product markets that use the ideas that result from innovation often characterize R&D-intensive industries. There are several reasons for this. The first, of course, is patent or other IP protection. Second, R&D investment is usually a fixed, sunk cost. The investment will only be justified if these costs can be recovered with the expected rents associated with innovation. Many industries other than high tech have significant fixed, sunk costs—for example, transportation industries such as railroads and ships; power plants; and many entertainment products such as movies, music recordings, books, and television production.[6] It is probably no accident that these industries are or have often been regulated, and many have been the subject of some very complicated and famous antitrust cases.

Yet another reason for high concentration in R&D-intensive industries is demand-side *scale economies*, or *network externalities*, which occur when a consumer's value for the product is increased by other consumers' presence. Direct network effects can generate this—a consumer values a communications network more highly as more people join the network. It can also be generated indirectly by supply of complementary products. For example, the value of a computer operating system is greater if more consumers purchase the same operating system, because then more applications will be developed for it. When this happens, competition among applications is more likely, leading to lower prices and higher quality, valuable upgrades to the operating system are more likely, and continued customer support can be expected. Demand-side scale economies lead to concentration of technology. If the network effects are large enough, it is difficult for a small, incompatible competing technology to survive.

The output of R&D—ideas—is primarily not consumed directly, but incorporated into goods and services that are consumed. The previous paragraphs follow much of the writing in this area by implicitly assuming vertical integration between the R&D stage and the commercialization of the innovation. It is possible, and often the case, that a monopoly patentholder will choose to license its innovation widely. This preserves downstream competition, although the downstream firms often face a monopolistically set input price for the licensed technology. Licensing to create efficient deployment of a technology can be hampered by appropriation problems. If a technology has weak or no patent protection, attempts to license the technology run the risk of appropriation by potential licensees. If part of the licensing negotiation reveals the innovation, the potential licensee may choose to reject the offer and develop goods or services based on the innovation itself. If the risk of appropriation is high absent patent protection, the innovator may only be able to earn a return on its technology by commercializing it and reaping the benefits of being a first-mover in the market. Appropriation may still occur, but perhaps only after the innovator has established a position in the market. Thus, the implicit assumption of vertical integration is often justified in the absence of adequate patent protection. This suggests an often overlooked benefit of patent protection—it allows for efficient allocation of an innovative technology to the companies that can use it most effectively.[7]

Similarly, although network effects lead to a small number of surviving technologies, the technology need not be controlled by a single company. Network externalities lead to a single protocol for fax machines, but the protocol is not controlled by a single company, so there can be a great deal of technological competition among fax machine suppliers. In many situations, however, companies do compete with proprietary, incompatible technologies. Then, network effects can lead to concentration of both technology and market power.

We, therefore, do not adopt a view that R&D-intensive industries are inevitably monopolized and therefore antitrust law can do no more than favor one monopolist over another. We do believe that R&D-intensive industries are more prone to market concentration and the exercise of market power than most others, that there can be significant social value from market power in these industries, but that it is not necessarily the case that only one technology must survive for efficiency reasons.

The combination of dynamics, uncertainty, and market power leads to one of the most important features of many R&D-intensive industries—an important form of competition is in R&D to replace the existing technology winner that has static market power with another based on improved technology. This form of competition occurs throughout the computer, pharmaceutical, and chemical industries, as well as most other R&D-intensive industries. Called *creative destruction* or *Schumpeterian competition,* it is not the type of competition that antitrust enforcement typically tries to protect, but assuring its efficiency may be an important role that antitrust policy should play in R&D-intensive industries as opposed to others.[8]

Another feature of R&D competition is that it may involve redundant investment. Any type of private investment may involve some degree of rent-stealing from competitors, i.e., part of the return from investment comes from reducing or eliminating the rents available to others. This effect may be especially pronounced in some forms of R&D competition. For example, if two firms follow similar research programs to develop a patentable technology, it becomes a race, and the advantage to consumers over a single firm engaging in the research may be small. Free entry into the race may lead to either too much R&D or too little R&D, and the division of the resources among competing projects may not be optimal.[9]

III. Merger Policy in R&D-Intensive Industries

With these (mostly) familiar characteristics of R&D competition in place, we can now address the role of antitrust policy towards these industries. In this section, we take on the question of whether or not it is appropriate to consider "innovation markets" as distinct from product markets for the purpose of merger analysis. Gilbert and Sunshine (1995) make this suggestion; antitrust authorities have investigated the impact of mergers on R&D; and the U.S. Department of Justice (DOJ) has blocked at least one merger on the basis of anticipated reductions in innovation using the concept of "innovation markets."[10]

Mergers in R&D-intensive industries have become quite common in the past decade. The pharmaceutical industry has had several major mergers and numerous smaller ones; defense contractors have undergone extensive consolidation, as have telecommunications companies. This is in contrast to the 1980s, when R&D-intensive industries had not been the scene of much merger activity.[11]

In a free market economy, a voluntary decision of two firms to merge should be made because the firms believe that their joint value exceeds the sum of their independent values. This is generally because they believe that there are efficiencies associated with combining the two companies. However, some mergers can lead to a reduction in competition that causes output to decline and consumer prices to rise.[12] It is commonly accepted, as a matter of theory, that a reduction in competition from a merger can have these undesirable effects. Large-scale cross-sectional studies of the relationship between concentration and price suffer from severe measurement and causality problems that make it difficult to assess the general relation between concentration and pricing. However, there are also several empirical studies of individual industries which show that reductions in the number of competitors or increases in market concentration can harm consumers by increasing price.[13] Overall, there is both empirical and theoretical support for an antitrust policy aimed at preventing mergers that so concentrate an existing product market so as to make price increases likely.

Current antitrust enforcement focuses on short-run anticompetitive harm. If the antitrust authorities can show that price would rise in the first two years after the merger, the merger is likely to be enjoined. Arguments that significant efficiencies will be realized in subsequent years are likely to have no influence. And for good reason: Antitrust authorities are acknowledging that predicting the future is hard.

Future benefits from a merger, as well as future harms, should be discounted for time and the likelihood that they will actually occur. Short-run harm to competition is more immediate (by definition), and probably more predictable.

The potential-competition doctrine takes the small step of logic to extend antitrust merger review to firms that do not currently compete but might compete in the future in the absence of the merger. In theory, the issues are identical to those in a merger among current competitors. As a practical matter, however, one must predict the effect on competition in the more distant future. Questions that should be addressed include: If the merger occurs, will there be more entry by others? Absent the merger, will the potential competition turn into significant actual competition? How will competition in the market evolve over the next several years with and without the merger? Since predictions like these are quite unreliable and mergers tend to generate efficiency gains, antitrust regulators should and do set a high standard of justification for blocking a merger on potential-competition grounds.

If the potential-competition doctrine is a small step in economic logic from the usual antitrust policy aimed at firms actually competing, then the innovation market doctrine may seem to be only another small step further. The only difference between the two doctrines may seem to be that one is about future competition in an existing product market, while the other is about competition in R&D which leads to future competition in current or future product markets. Yet, it is no small step in logic to reach the conclusion that concentration of an innovation market is undesirable or that antitrust policy should seek to block mergers that significantly increase such concentration.

To reach such a conclusion, one must accept the theoretical and empirical validity of the following claims:

1. Reducing R&D expenditures is undesirable.

2. If there are fewer firms performing R&D, there will be less aggregate R&D and fewer new products.

3. There are not enough other firms to perform R&D and develop future products to compete with the future products developed by the merged firm.

Neither theoretical nor empirical analysis has established the general validity of any of these three claims.[14] We will discuss each claim in turn.

Reducing R&D Expenditures is Undesirable

Since R&D expenditure is an input, not an output, it is desirable only because it leads to knowledge that ultimately benefits society, as would occur if new products embodying the knowledge were produced. As with all inputs, efficiencies can cause output to be produced with less inputs; a merger that reduces R&D expenditure may be beneficial if it allows the R&D to be conducted more efficiently. Since competing R&D expenditures may be duplicative, a merger that eliminates redundancy may lead to the same knowledge produced at lower costs, or even to greater knowledge at lower costs. The same or increased knowledge would likely be embodied in the same or greater number of products, so long as there was no traditional market power problem with the merger in the consumer market.[15] Other efficiencies beyond elimination of redundancy could be an enhanced interchange of ideas and sharing of resources. Although situations where R&D reductions are efficiency-enhancing may be hard to identify, it is incorrect to conclude that any reduction in R&D is necessarily bad for consumers. It can be a difficult question whether a merger that will reduce R&D should be blocked, even if the authorities cannot demonstrate a reduction in output.

A comparison with other sources of cost savings in a merger is useful. We would never say a merger is anticompetitive simply because it leads to reduced overhead or to labor or materials savings. It would be necessary to study whether or not there would be output reductions.[16] Possible reasons to adopt a different standard for R&D reductions from that for other cost reductions are that it may be difficult to prove the output effect and policymakers may conclude that consumers are generally harmed by R&D reductions.

Indeed, it is very difficult to measure the output from R&D. This is because the ideas generated are idiosyncratic, their value is hard to measure, and the R&D process takes time and its outcomes are uncertain. Estimating a production or cost function for R&D would be virtually impossible unless one used broad proxies, such as patents issued, for output.

Even if one could show that less R&D would lead to fewer new products, the question still remains whether this is bad for society. It is well known that competition may result in either too few or too many new products. Unlike output restrictions, which cause unambiguous consumer harm, a reduction in the rate at which new products emerge may or may not be desirable. This is recognized in limited patent length and other aspects of IP policy.

The antitrust treatment of R&D should be viewed in the context of all aspects of IP policy. Maybe one could have the same amount of innovation with shorter or narrower patents and weaker antitrust enforcement or vice versa. It simply does not follow from any theoretical argument that, given current patent policy, using antitrust enforcement to block reductions in R&D is good for society.

There is some empirical evidence on this point.[17] For much R&D, it appears that the social rate of return exceeds the private one, suggesting that more R&D would be desirable. In addition, the recent literature on the value of new goods suggests that consumer returns from innovation are very large. However, the correct question compares the marginal social return from R&D with the marginal private return, yet most of our evidence is on average returns. Even if we accept that more R&D would be beneficial (and we tend to hold this belief), there is no evidence to suggest that stricter antitrust enforcement is a more cost-effective way to achieve this than increased patent protection or other changes in IP policy.

One approach that addresses the possible efficiency of eliminating duplicative R&D, and at the same time achieves some of the benefits of competition in the output market, is a research joint venture. Such a venture can be either open to any firm that chooses to join or limited to only a few firms. It can provide the fruits of its labors to the participating firms that compete in the output market. By making the R&D input available to several rival firms in the output market, some of the benefits of competition can be preserved. Although structuring a research joint venture can raise complicated issues, it can be a viable substitute for a much less competitive output market structure.[18] Antitrust authorities recognize this and have loosened enforcement against research joint ventures.

Fewer Competing Firms Will Reduce R&D

There is no consensus in the theoretical or empirical literature that reduced competition leads to less R&D and fewer new products. Not all new technology can be patented, so imitation and reverse engineering are possible in many industries. For example, some software is protected only by copyright, so a software developer can legally implement its own version of innovative features in a competitor's product.

If imitation is possible, a more concentrated market can permit the innovator to capture more of the value of its innovation. In this way, market concentration could help solve the appropriability problem and thereby increase innovation.

Patent protection can reduce or eliminate the appropriability problem, but it does not solve the lack of theoretical consensus on the relation between concentration and R&D activity. Various theories predict that competition can have significant influence on R&D activity; the problem is that the results can go either way. For Schumpeter (1943), market concentration aids innovative activity because large firms can absorb the risks and costs of the latter. For Arrow (1962), a competitive firm will typically have a greater incentive than an established monopolist to invest in R&D, since it can gain the entire monopoly profits in the market while the incumbent will only gain the incremental monopoly profit from the innovation. This holds if the innovator captures the entire market. However, if an innovative entrant and the incumbent compete, then the incumbent may have greater incentive to invest to avoid the lost industry profits associated with duopoly.

Sophisticated theoretical models of patent races show that competition to discover and patent an invention could lead to too much aggregate R&D expenditure. There are two external effects of increased R&D investment: it lowers rivals' payoffs, and the innovator does not capture all the social value of its invention. These two effects go in opposite directions. The theory remains ambiguous, and the size of these two effects is difficult to measure in any real setting.

The empirical literature provides no firmer foundation for an antitrust policy designed to prevent mergers that will concentrate innovation markets. Although some early research suggested a positive relation between R&D and concentration, subsequent research has failed to confirm this result. In an extensive survey, Cohen and Levin (1989) conclude, "The empirical results concerning how firm size and market structure relate to innovation are perhaps most accurately described as fragile. . . . These results leave little support for the view that industrial concentration is an independent, significant, and important determinant of innovative behavior and performance."

In summary, neither theory nor empirical work provides any general justification for an antitrust merger policy aimed at preserving competition in R&D markets. They certainly tell us nothing about essential policy issues, such as at what levels of concentration should there be concern. Do economists really know so little about R&D and concentration that there is no basis at all for an antitrust policy aimed at preventing a reduction in R&D competition? The short answer is yes, but it is important to note that the empirical literature, for the most part, relies on cross-sectional studies across industries, which cannot control for the effect of industry-specific factors. Such studies, like similar ones for price and concentration, do not provide a sound methodology for uncovering such a pattern if one exists. Moreover, industries probably vary too much for one theory to fit all.

This means that a study of an individual industry over time could find a stable empirical relationship between concentration, R&D activity, and innovation, all else equal. Indeed, it is precisely the industry in which the merger is proposed that should be studied to see if a pattern exists. If no data are available to perform such a study, then there is no other general economic literature to justify an antitrust challenge that concentrates R&D. It is precisely when data on individual industry behavior are available that the economist should try to use his empirical tools to detect whether there is any effect of concentration on R&D competition.

The empirical academic literature on the relationship between concentration and price has shifted to industry studies over the past twenty years. In order to identify a relation, there must be time series or cross-section variation in concentration. In addition, since this variation is usually endogenous, one needs instruments to identify the effect of concentration. This has limited the number of industries where such studies can be done. The data problems are more severe with R&D. We can think of no good examples where there is useful geographical cross-section variation in R&D—ideas have no geographical boundaries, and innovations are typically implemented everywhere. One could imagine studies across, say, different classes of pharmaceuticals or defense-related R&D projects, but the differences in the R&D production functions could be difficult to identify. Similar problems exist over time—did R&D go down because concentration increased or because the opportunities for technological improvements declined? Thus, although industry studies can be appropriate, we think that they could well raise difficult empirical issues.

There Are Not Enough Other Firms to Produce the R&D in the Future

Of the three logical underpinnings for an antitrust merger policy aimed at preserving competition in R&D markets, this one may be the most troublesome. The basic problem is similar to the one that arises in the application of the potential-competition doctrine, where all future competitors have to be identified in order to determine whether the elimination of a single one would harm competition. Identifying future competitors for a known product strikes us as generally pretty hard, especially as the time period lengthens. Identifying future competitors for an unknown product is likely to be an order of magnitude more difficult.

In order to identify an "innovation market," one must include the innovation activity of all those firms with R&D efforts that might result in products competitive to the ones that the merged firm may develop. This means that there typically will be firms in the "innovation market" who do not currently compete in any way with the firms that propose to merge. Indeed, because the results of R&D are so difficult to predict, the analyst may be unable to determine all, or even most, of the relevant firms that might produce competitive products in the future. This problem becomes more severe the longer it takes before any new products are expected to come to market and the more uncertain and rapidly changing is the industry.

Indeed, it is often impossible to predict which industry, let alone which firm, will develop a particular type of new product. R&D in one product has frequently led to unpredictable applications elsewhere. For example, Teflon was discovered as a byproduct during an experiment on refrigerator gases. It has since been used for a wide variety of applications such as microchip packaging, nonstick coatings, and artificial arteries.[19] Research on dressings for wounds led a researcher to discover a new coating that leaves fabric waterproof but breathable. The company, Biotex, that developed this product did so as part of its research on artificial hearts and is now venturing into the textile business.[20] In 1988, Wayne Matson developed a machine to analyze brain chemistry. Soon, it was clear that the machine had other uses, and it has since been used to identify the components of fruit juices.[21] Corning, a glass company, became a leading supply of telecommunications equipment based on technology that would have been impossible to predict before the fact.

These examples illustrate that it can be hard even to contemplate all the sources of tomorrow's products. How many economists or lawyers would have predicted even ten years ago that R&D in computers, cable, and telecommunications would result in products that compete with each other? The implication is that innovation markets will tend to be quite broad, so that it is unlikely in many cases that a merger should raise concerns about significantly diminishing R&D competition.

Despite the entertaining anecdotal evidence about the serendipitous nature of innovation, a number of recent studies cast doubt on a general conclusion that innovation is, on average, serendipitous. Methe, Swaminathan, and Mitchell (1996) show that established firms are often sources of major innovations in telecommunications and medicine. Note, however, that the industry definition of telecommunications and medicine used in these articles is significantly broader than market definitions that are typically used in antitrust policy. Prusa and Schmitz (1991) show that new firms have a comparative advantage developing new categories of software, while established firms have a comparative advantage developing improvements to existing categories of software. Tether (1998) shows that although small firms have more innovations per employee, large firms develop more important innovations. However, Kortum and Lerner (2000) show that venture capital accounts for a disproportionate share of industrial innovation.

Thus, in some limited circumstances, an analyst may be able to identify the firms that are likely to be pursuing R&D that will lead to competing products several years in the future. Perhaps in some industries such as pharmaceuticals, where R&D is becoming more systematic and there is a regulatory pipeline (e.g., FDA) for approval, or defense products, where government funding or approval is required, such identification is possible. But the longer the time period, the less reliable is the prediction. Finally, in those rare cases where the analyst can confidently predict that a merger will lead to a decline in competition in R&D which, in turn, will lead to a decline in competition in new products, it would seem likely that the potential-competition doctrine could be used to prevent the merger. The use of that doctrine might involve applying it to products that do not now exist but will exist in the future with a high degree of certainty. This seems like a logical and straightforward use (or extension) of the doctrine. We prefer the potential-competition doctrine to the "innovation market" approach because the former, unlike the latter, focuses on the effects in an output market of reduced competition (i.e., price, quality, speed of introduction), instead of the more general and harder-to-predict effect of reduced R&D on unspecified future products.

Not all R&D is designed to create new products; much R&D investment is designed to lower the production cost of existing products or to make incremental improvements in them. In such situations, it is more likely that an insider than that an outsider will develop such an improvement. Although in these markets it may be possible to define the set of firms that compete in R&D, it is also in these settings that some of the problems identified in the preceding sections become most severe. Imagine that two manufacturers of a particular product wish to merge. There is no direct antitrust problem in the product market, because there are many other competitors. But the two firms compete in R&D to produce the product less expensively while none of the other product manufacturers compete in R&D. It is exactly in a situation such as this that a merger could increase R&D by reducing appropriation risk or eliminating redundancy. The impact of successful innovation on product market competition is also unclear in such a setting. If the innovation is patented, the diffusion may be the same with or without the merger. If it cannot be patented, the innovation may be more widely used if there is a merger.

Application of the Doctrine

The doctrine that mergers can concentrate an innovation market and harm R&D competition has been applied in merger analysis. One of the first such cases was the proposed acquisition by ZF Friedrichshafen AG of the Allison Transmission Division of General Motors. Allison makes automatic transmissions for certain types of trucks (e.g., refuse trucks) and buses. ZF also makes transmissions, including automatic ones, for certain trucks and buses. The U.S. DOJ issued a complaint to stop the merger in November 1993, and the deal then died. In its complaint, the DOJ alleged that the acquisition would reduce competition in two product markets, one for refuse trucks and one for transit buses. It also alleged that competition would be adversely affected in the worldwide market for innovations in automatic transmissions. Specifically, the DOJ was concerned that ZF would not continue to engage in R&D in as vigorous a fashion after the merger.

Assume that it would have been possible to allay the competitive concerns about the two traditional product markets by having ZF license an independent third party, and further suppose that there were at least some efficiencies motivating the transaction. The transaction was stopped in 1993, so consumers have been deprived of eight years of benefits (indeed, the DOJ can influence the size of the benefits that consumers receive by the type of license arrangement it accepts). As of 2002, we understand that no significant new products in automatic transmissions have emerged from ZF, nor has ZF become a more vigorous competitor. In fact, we understand that ZF has withdrawn form the refuse-truck market.

We do not want to comment on whether it was wise to issue the complaint.[22] We simply point out that that the benefits from R&D that were the concern of the DOJ are highly uncertain and difficult to predict. It is therefore useful to follow this case and others like it, to see whether consumers ever receive any benefit from the R&D that was the concern of the DOJ or FTC in blocking a merger and, if so, when. The expectation of these benefits should be discounted and compared with the immediate efficiency benefits that could likely have been achieved by a well-structured settlement. Only by systematically keeping track of the subsequent evolution of industries will we be able to decide what are good antitrust merger enforcement policies.

IV. Monopolization in R&D-Intensive Industries

R&D-intensive industries are prone to short-run exercise of market power. Patent protection, economies of scale in R&D, network effects, and significant horizontal and vertical differentiation all can lead to some market power. In many situations single technologies dominate the market, and sometimes a single firm controls those technologies.

Since this is an inherent feature of R&D-intensive industries, it would be seriously misguided to employ the antitrust laws to prevent the exercise of market power in these industries. Obviously, not allowing a patentholder to exercise market power would defeat the purpose of the patent laws. Even absent patent protection, market power derived from successful R&D creates incentives for R&D that are beneficial.

Fortunately, it is a basic tenet of antitrust law that monopoly power is not, in itself, illegal. Only certain categories of conduct designed to obtain, extend, or preserve monopoly are illegal. The types of conduct that have been successfully challenged include predatory pricing, exclusive dealing, and tying.

Since we are generally unconcerned about market power initially obtained through R&D investments, we will focus on the role of antitrust policy with respect to conduct that extends or preserves legally obtained market power in R&D-intensive industries.

Ever since Schumpeter introduced the idea, many commentators have emphasized that competition in R&D markets is largely about innovation designed to replace existing firms that have market power. This dynamic competition has received so much attention that it has several names: "Schumpeterian competition," "creative destruction," and, in the context of computing systems, "dynamic platform competition."

It follows that competition policy in R&D-intensive industries should focus on the performance of this dynamic competitive process. Perhaps we should not worry about the exercise of static market power, or even its exercise over long periods of time, but we should worry about firms with static market power distorting the dynamic innovation competition for future market power. It does not yet follow, however, that there is a role for policy intervention in this process, nor does it follow that antitrust is the best policy tool to regulate this process. However, we do think it is an area that merits careful analysis and continued research. We take a few preliminary steps in this section.

A current technology leader with market power would like to earn as much rent as possible from its intellectual capital for as long as possible. Many of its activities will affect its ability to sustain its position. They include investment in R&D to develop product improvements or next-generation products, long-term contracts with customers, tying or bundling, changing compatibility with complementary products, cross-licensing technology deals with potential competitors, and aggressive pricing.

Some of these actions may reduce the likelihood that a competitor will replace the existing market leader, they may reduce R&D investments by potential competitors, and they may reduce social welfare. The correct policy response cannot be that a company that has legitimately obtained market power through its innovative efforts is under a legal obligation to adopt strategies that (someone believes) are in the public interest. It should not always be illegal to undertake a strategy that is in the firm's private interest, simply because there is a different strategy that (someone believes) leads to higher consumer welfare. Such a policy would be unworkable, would put an impossible burden on innovative firms to evaluate social effects of a multitude of strategies, and is completely inconsistent with free market principles.

Throughout antitrust law, courts have identified certain classes of monopoly conduct as potentially suspect. In most cases, after certain preconditions are met (such as market power in a well-defined antitrust market) courts follow a rule-of-reason analysis. In some situations, this inquiry will simply try to weigh the anticompetitive harm against procompetitive benefits. For some allegations, such as predatory pricing, the plaintiff must make a number of specific showings (below-cost pricing and likelihood of recoupment).

Analyses and arguments over the choice of the best rule for particular types of conduct have filled volumes of law and economic journals. Most agree that the factors to consider include the likelihood of incorrectly punishing procompetitive conduct vs. the likelihood of failing to identify anticompetitive conduct, the costs of different types of mistakes, the social return from eliminating the anticompetitive conduct, and the value of explicit guidelines that allow companies to evaluate the legality of various actions.

The question for us becomes what types of rules should apply to conduct by a monopolist in an R&D-intensive industry that may reduce Schumpeterian competition. For many types of conduct, the basic theory underlying conventional antitrust analysis applies to R&D competition as well. The comparisons are useful. For example, there is a well-developed theory of exclusive dealing where exclusive contracts can lead to less-competitive actions by competitors, including reduced investment, exit, or entry deterrence.[23] Similarly, a monopolist in an R&D-intensive industry may sign long-term contracts with customers. This could induce a potential competitor to reduce its investment in R&D and could occur when a patent is about to expire and the contracts act to deter effective generic entry.[24]

Applying the theories of antitrust harm to the R&D setting will usually create a more difficult factual inquiry. In most cases, it would be very difficult to develop compelling evidence on the level of R&D spending by potential competitors in the but-for world—in section III we argued that it may not even be possible to identify who potential R&D competitors are. Even if one could identify the likely R&D competitors and their but-for R&D investments, it would be difficult to determine the social value of such an investment and compare it with any efficiency gain. And once again the conflict between monopoly-power-creating IP policies and antitrust becomes evident. Are we better off with patent protection for 20 years and tough antitrust rules that reduce the likelihood of extending the monopoly through exclusive contracts, or with patent protection for 17 years and weak antitrust rules? We have no broad answer to this question. If the conduct has the effect of stifling the dynamic process of creative destruction, the social costs may be large and antitrust enforcement seems justified. But it might be very difficult to know in a particular setting if this is the case.

A similar point applies to using the antitrust theories related to tying and bundling. The theoretical arguments of how tying could lead to anticompetitive harm include Whinston (1990), Carlton and Waldman (2001), Choi and Stefandis (2001), and Nalebuff (1999). The basic idea in all these models is that tying makes it more difficult for an entrant to compete. In Whinston, it may be impossible to get to sufficient scale to compete in the tied market and thereby allow a monopolist to extend its monopoly power into the tied market. In Carlton and Waldman as well as Choi and Stefandis, a similar but dynamic process makes it more difficult for entrants to compete in the tied market, while in Nalebuff the pricing advantage of a bundled product makes it more difficult for an entrant to compete in either market.

The basic competitive effect of the monopolist's strategic behavior of tying or bundling in these models is reduced investment by a competitor. In an R&D-intensive industry, the strategic conduct can therefore reduce competitive R&D investment. As just discussed, applying an antitrust theory of harm in an R&D setting can be complicated, especially when the tie involves incorporating additional functionality into existing products. Again the possible harms from stifling the innovative process will often be hard to weigh against the possible benefit of raising the return to an innovator, and again the relation between antitrust policy and IP policy must be considered.

V. Schumpeterian Competition between Open and Closed Systems

Firms in some R&D-intensive industries have to decide whether to make their product compatible with complementary component products or to make all components itself. A firm with market power in one or more components of an open system may choose to close its system by creating incompatibilities with other products, thereby reducing competitive R&D investment for subsequent generations. This same choice can appear in non-R&D-intensive industries, but here the choice could have a great influence on future R&D competition.

The theoretical literature on open vs. closed systems considers competition for a single generation of the technology but does not focus on competition across many generations.[25] The single-generation models reveal a trade-off in the choice between open and closed systems. It is more difficult to win with a closed system against an open system, all else equal—the closed system must provide better value to consumers than mixing and matching the best components across all producers of open-system components. However, the gains from winning with a closed system may be greater because the closed-system provider can earn greater rents under certain circumstances.

Placing the closed–open-system choice in the context of multiperiod Schumpeterian competition can change the trade-off significantly. We use a simple two-period model of Schumpeterian competition in order to compare R&D investment incentives between open and closed systems. Here we present an example of the model to demonstrate how a leading component firm may choose to close a system in order to deter dynamic competition that could replace it. The sole purpose of the admittedly simple model is to illustrate an overlooked incentive for dynamic competition to produce closed systems.

Consider the following model. There are three components of a system, each of which is necessary for the system to have any value to a user. For each component, three firms compete to develop the component. Prior to the first period of R&D, firms that research different components can merge in order to develop a closed system. If they do not merge, they each develop a component for an open system.

In period 1, each firm chooses whether or not to invest in R&D. If it invests in R&D, it develops a component that has uncertain value to consumers. If a consumer selects an open system, he can mix and match among all open components. If he chooses a closed system, he must choose the single element of the closed system for each component. Consumers are all identical, so each chooses the same system.

We denote the three components of the system by A, B, and C. There are three firms (subscripted by 1, 2, and 3) with the capability to develop each component, so there are nine firms overall. In order to develop a component, a firm must incur R&D costs of K; in return it develops a component that has quality $V/3 + \theta$, where θ is a random variable. In our numerical example, θ is a discrete random variable that takes on the value $-\varepsilon$ with probability α, ε with probability α, and 0 with probability $1 - 2\alpha$. Demand for the system is linear with unit demand, and the intercept is the total quality of the system, $V + \theta_A + \theta_B + \theta_C$, which we denote by Z. If the total price of the system is P, demand is $V + \theta_A + \theta_B + \theta_C - P$.

Once each firm makes an R&D investment decision, the outcome becomes known. We assume the following about competition: First, it is winner-take-all, so the highest-quality system gets the entire market. If there is a tie for the highest-quality component, each wins with probability ½. Second, losing firms drop out of the market, so the quality of their technology does not constrain the winner. (Assume that there is an additional small cost of product development, so that a firm with an inferior component chooses not to remain because it will make no sales.) Third, if there is an open system, each component producer chooses its price simultaneously and noncooperatively. In equilibrium each firm charges $Z/4$, quantity is $Z/4$, and each firm earns profits of $Z^2/16$. If all three firms for a given component engage in R&D, the expected quality for that component will equal $V/3 + \max_i \theta_i$ where subscript i indicates a firm. This equals $V/3 + 2\alpha(1 - \alpha)\varepsilon$.

Prior to R&D investment decisions, a firm can choose to vertically integrate and develop a closed system.[26] It then develops a closed system, i.e, it produces components that are compatible with each other but incompatible with any competitors' components. A closed system wins only if the sum of the values of its three components exceeds the value of the best open system, which equals the sum of the values of the best three components. Since there are two open firms for each component and consumers can mix and match to choose the best of each component, the closed system will be disadvantaged. The expected quality of a closed-system component is simply the expectation of a single draw for a component, which is $V/3$. For example, if α = ⅓, the probability of a closed system winning is approximately 0.24, which is less than the ⅓ probability of winning for each component in an open system.

Although a closed system is less likely to win, its profits are greater conditional on winning. The closed-system monopolist will set a price of $Z/2$ for the entire system. Its profits will be $Z^2/4$, which exceeds the entire open system's profits of Z^2. If α = ⅓, an open component has a 50% greater chance of winning, but 25% lower profits conditional on winning. With these parameters, in a single-period model, the equilibrium is for all firms to choose open-system components.

However, when one introduces the dynamics of competition, the results can change dramatically and favor a closed system. To see this we model a second period of R&D investment. This R&D competition is Schumpeterian; if a firm invests, then there is some probability it will develop the technology for a component that surpasses the quality of the incumbent monopolist's component. There is no issue of compatibility across generations, i.e., there are no consumer switching costs. Prior to period 2, a winning open-component firm from period 1 may try to integrate vertically to form a closed system.

In period 2, each firm again chooses whether or not to invest in R&D. To keep the model simple, we assume that an investment of k generates a probability γ that component i will have a value that surpasses the existing technology by μ. If no improved system is developed, consumers will continue to purchase the old system. Again, to simplify the analysis, we assume that the incumbent and one other firm have access to this R&D capability for each component. Finally, to avoid the possibility of mixed-strategy equilibria, we assume that the incumbent moves first; it has the ability to commit to engage in R&D prior to any challenger.

This game is subject to well-understood forces. An incumbent has less incentive to invest as its fear of entry subsides, because it already earns monopoly rents—it cares only about incremental rents, while the entrant can replace the monopolist and earn both the incremental and base monopoly rents. Since the incumbent can move first, however, for some parameter values it may choose to invest in order to deter the entrant from investment.

For each element of the open system, it is easy to characterize the equilibrium. For small k, both invest. As k increases, holding all other parameters constant, the incumbent does not invest and the entrant does; as k continues to increase, preemption becomes possible, and the incumbent invests and the entrant does not. For very large k, neither firm invests.

The key difference between an open and a closed system is that in the closed system, an entrant for a single component cannot invest in R&D, succeed, and thereby displace the incumbent unless every other component's potential entrant also invests in R&D and succeeds. We assume that each first-generation component is protected by a patent, so that if a company develops a single new component to compete against a closed system, it cannot obtain other components to provide a product to consumers.[27] The probability of three innovations is γ^3, so unless γ is close to 1, the likelihood of displacing a closed system is small relative to displacing at least one element of an open system. Thus, for some parameter values, there will be R&D investment by entrants if the incumbent system is open, but there will be no R&D investment by entrants if the incumbent system is closed. Closing a system could lead to dramatic reductions in dynamic innovation competition.

If the closed system is unchallenged, the incumbent monopolist will invest in R&D only if the incremental profits cover the cost of innovation. Since it does not reap all the benefits of product improvement, there will be less R&D investment than is socially desirable. An open system is likely to lead to more competitive innovation, but the level of innovation could be socially excessive. The motivation of substituting oneself for the existing monopolist as the recipient of existing monopoly profits is rent-seeking that has no social value. However, the only way to do this is to engage in socially valuable innovative activity.

In many settings, it is possible to convert an open system to a closed system by imposing incompatibilities at low cost. In our model, after the winning components are determined in the first stage of R&D competition, the winning firms could choose to create a closed system through vertical integration or contractually. If possible, this would allow them to deter competitive innovation without having to bear the heightened risk associated with developing a closed system in the first stage.

One way to interpret the model is in terms of externalities. The beneficiaries of open systems are future consumers and firms that will have R&D opportunities in the future. If all of these parties could get together to provide appropriate subsidies and coordinate R&D efforts, efficient displacement of the closed-system monopolist would occur. Such coordination is, of course, impossible. The result is that too little investment in displacing a closed system may occur and that there may be an incentive for open-system suppliers to coordinate and close their system.

The model is most similar in structure to Nalebuff's papers on bundling.[28] These papers focus on the difficulty for a single-product producer to compete against a bundled product. In his model, there are no complementarities in demand, but pricing strategies by the incumbent make single-product entry less profitable and play a similar role to the independent uncertainties of R&D that drive our model.

There are a number of possible extensions to the model. It may be extreme to assume that innovation in all three components is necessary to replace the existing technology. If one develops a much superior single component, it may be possible to use nonproprietary technology for the other components. This may reduce the advantage of a closed system, but not eliminate it completely. The closed-system monopolist will have an incentive to devote significant resources to R&D for any component where significant competition exists. Such a monopolist has the ability to focus its R&D efforts on the component that is most vulnerable. A single-component competitor will generate external benefits for other component firms; unless they can coordinate and subsidize the innovative firm, the incumbent's advantage and ability to deter remain. In addition, the incumbent could try to acquire any firm that is successful and incorporate the component into its system.

Open systems have additional consumer benefits when there is horizontal differentiation among components. Variety of components that are compatible can add significant value. This may be another source of welfare loss from closing a system.

The model implies that the benefits to winning with a closed system may be large—short-run and long-run market power without the need to invest too heavily in R&D to maintain one's position. This suggests that firms could devote enormous resources to the competition to have the winning closed system. The model does not allow variable levels of R&D investment. In a richer model, the efficiency question is whether this compensates for the welfare losses from the closed system. There are several reasons to think that it would not. First, there may be significant diminishing returns of consumer benefits and perhaps even of the private benefit from incremental spending on R&D or marketing to become the initial winner. If the former is the case, consumers do not benefit much from the intense competition to be the monopolist. If the latter is the case, expenditures may not be too large.

Second, if initial R&D is very uncertain, no firm may try to innovate with a closed system, because the probability of beating a mix-and-match open system would be too small. Each firm will instead develop single components or several components as part of an open system. However, if at any point one company dominates an important component of the open system, it may have the ability to develop a winning closed system at low cost. If it is technologically possible to take the winning component and develop proprietary interfaces with other components, then the firm could acquire or develop the other components. The component producers, fearing obsolescence, may be willing to sell out at a low price.

We have developed a story of how Schumpeterian competition between closed and open systems could result in too little innovation and continued exercise of static market power. If one accepts the logic of the basic story, the next question is whether or not antitrust policy should play a role in improving performance. Although the model suggests close scrutiny of mergers or conduct that creates a closed system, the exact role for antitrust is not straightforward. It is first necessary to define the conduct that is suspect—the government certainly cannot simply prohibit offering a closed system, nor can investing a great deal in R&D to make the system better than rivals be illegal. In many circumstances, closed systems may create consumer value by allowing more effective coordination among components, and competition to become the winning closed system may be effective. Furthermore, the determination of the optimal level of R&D remains elusive, so it does not follow that simply because creation of a closed system may reduce R&D, the new level of R&D is less than optimal.

One type of conduct that possibly could present an antitrust problem is actions a firm with market power takes to make a system closed or more closed.[29] Yet the rule-of-reason analysis needed would be very difficult and require a great deal of technical sophistication of the courts. Antitrust laws may be too crude a policy tool for dealing with these problems. Maybe subsidies for maintaining open systems or for open-standard-setting organizations would be more effective.

A second set of policies that may be justified are those which promote open systems, perhaps through limited subsidies, tax benefits, lessened antitrust restrictions on institutions that promote standards, and increased antitrust scrutiny of conduct that subverts such institutions. Standard setting can be a critical element in having an open system. Therefore, the strategic subversion of the standard-setting process can be especially harmful to competition between open and closed systems. In several recent court cases, companies have alleged that a rival participated in deliberations of collective standard setting in an effort either to obtain information to file patents that could then be asserted against those adhering to the standard or to encourage adoption of a technology for which they already had patent rights.[30] These acts occurred despite the reliance upon each other by firms in the standard-setting process to assure that the standards raised no patent issues. The subversion of the setting of open standards can defeat their purpose and could make it impossible for open systems to survive in competition with closed systems.

IP policy could play a significant role as well. Restrictions on the ability to patent certain types of interfaces or limitations on how such a patent can be enforced may be justified. In addition, government subsidies for research could include requirements for some degree of openness.

VI. Conclusion

Economic growth depends in large part on technological change. Laws governing IP rights protect inventors from competition in order to create incentives for them to innovate. Antitrust laws constrain how a monopolist can act in order to maintain its monopoly in an attempt to foster competition. Antitrust doctrines have for the most part been developed with a static setting in mind. There is a fundamental tension between these two different types of laws. Attempts to adapt static antitrust analysis to a setting of dynamic R&D competition through the use of "innovation markets" are likely to lead to error. Applying standard antitrust doctrines such as tying and exclusivity to R&D settings is likely to be complicated. Only detailed study of the industry of concern has the possibility of uncovering reliable relationships between innovation and industry behavior. One important form of competition, especially in certain network industries, is between open and closed systems. We have presented an example to illustrate how there is a tendency for systems to close even though an open system is socially more desirable. Rather than trying to use the antitrust laws to attack the maintenance of closed systems, an alternative approach would be to use IP laws and regulations to promote open systems and the standard setting organizations that they require. Recognition that optimal policy toward R&D requires coordination between the antitrust and IP laws is needed.

Notes

This paper incorporates parts of and extends testimony Carlton gave before the Federal Trade Commission's Hearings on Global and Innovation-Based Competition in 1995. We thank Greg Pelnar for excellent research assistance.

1. These questions have been the subject of much discussion. See, e.g, Carlton (2001, 2002), Evans and Schmalensee (2001), and Porter (2002).

2. See Posner (2001), especially pp. 276–280, for a discussion of the ability of courts to deal with technologically changing industries.

3. We note some examples of this in section III.

4. See Kremer (1998) for a discussion of how a system of prizes might work and the history of innovation prizes.

5. See Spence (1984) for a model of the trade-off between patents and subsidies.

6. R&D-intensive industries exhibit endogenous sunk costs because the level of R&D

spending is chosen by firms in a way that depends on competitors' R&D expenditures. Sutton (1998) shows how this leads to high concentration, independent of market size.

7. Hall and Ziedonis (2001) demonstrate that patent protection and subsequent licensing allows small semiconductor design firms to compete in innovation despite lacking the scale and resources to manufacture.

8. See Carlton (2002) and Porter (2002) as well as other articles in the "Symposium on the Antitrust Analysis of Mergers: Merger Guidelines v. Five Forces," *University of West Los Angeles Law Review* 7 (2002).

9. The idea of wasteful competition for rents has been analyzed by economists in many analogous settings.

10. This was the proposed acquisition of the Allison Transmission Division of General Motors by ZF Friedrichshafen AG in 1993. We discuss this case in more detail below.

11. See Hall (1988) and Pound, Lehn, and Jarrell (1986).

12. There is also a large literature arguing that agency costs can explain many mergers, i.e., a merger that is not value-enhancing may still be in management's interest.

13. See, e.g., Chapter 9 in Carlton and Perloff (2000).

14. This is not from lack of study. There is a large literature on each of these topics. See Cohen and Levin (1989) for a large survey covering these and other issues.

15. For example, consider an R&D joint venture by two competitors where both get to share in the cost-reducing technology produced by the joint venture, but still compete with each other in the product market. One can show that, under some circumstances, the joint venture will invest in the same amount of R&D as each firm would individually absent the joint venture. The result of the joint venture is the same cost reduction, the same product market prices, but a 50% savings in R&D costs. The joint venture is a Pareto improvement.

16. If one adopted the reasonable view that overall efficiency (not consumer welfare) was all that mattered, then one would look at the net surplus resulting from the merger.

17. See, e.g., Jones and Williams (1998).

18. See Carlton and Salop (1996).

19. See *Wall Street Journal*, October 4, 1984.

20. See *Wall Street Journal*, October 19, 1984.

21. See *Wall Street Journal*, February 5, 1990.

22. Dennis Carlton served as a consultant for GM and ZF.

23. See, e.g., Bernheim and Whinston (1988).

24. Nutrasweet signed long-term contracts with Coke and Pepsi shortly before its patent expiration.

25. Contributions to this literature include Besen and Farrell (1994), Economides and Salop (1992), Farrell and Saloner (1985, 1992), Katz and Shapiro (1985), and Matutes and Regibeau (1988).

26. To keep the exposition of the model simple, we focus on an equilibrium where there can be at most one firm with a closed system.

27. This is an extreme assumption that helps illustrate the basic point dramatically. The assumption can be weakened and the same basic forces will still apply. We discuss this point briefly below.

28. See Nalebuff (1999, 2000).

29. Economides and White (1994) discuss antitrust implications of closing a system and explain its relationship to tying and exclusive dealing. They do not focus on the impact of closing a system on innovation.

30. See, e.g., *Micron Technology Inc. v. Rambus Inc.*, U.S. District Court for District of Delaware, Civil Action No. DO-792; *Rambus Inc. v. Infineon Technologies*, U.S. District Court for the Eastern District of Virginia, Richmond, Civil Action No. 3:00 CV 524; and *FTC v. Dell Computer Corp.*, 121 FTC 616. Carlton has served as an expert for Infineon and Micron.

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