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Author
Gilbert, Richard J

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Chapter 26

COMPETITION AND INNOVATION

Richard J. Gilbert*

The Department of Justice and the Federal Trade Commission have frequently raised innovation concerns as reasons to challenge mergers. This chapter surveys the economic theories of innovation incentives and considers how the theory may inform antitrust analysis for merger investigations and other conduct that involve innovation. Competition can promote innovation by reducing the value of failing to invest in research and development. However, with non-exclusive intellectual property rights, competition can reduce innovation incentives by lowering post-innovation profits. There is some empirical support for these economic theories. The chapter concludes that economics can inform antitrust analysis for mergers and other conduct that could affect innovation, although it is important that antitrust analysis carefully consider the key factors that drive innovation incentives.

1. Introduction

Although U.S. antitrust enforcement has largely focused on arrangements that increase prices, market structure and conduct also may affect the supply of new products and improvements to existing products, with enormous consequences for economic welfare. Recently the effects of market structure on innovation have gained in importance as a consideration in antitrust policy and in the thinking of the antitrust agencies. The change is particularly notable in merger policy. The antitrust agencies now commonly challenge mergers in part due to a concern that the mergers will delay or prevent innovation.

This chapter reviews the economic literature relating incentives for innovation to market structure and conduct. The emphasis in this chapter is on the relationship, if any, between competition in today's market and incentives to invest in research and development (R&D) for tomorrow's products. This chapter does not deal with competitive effects that may occur in markets for goods and services other than to the

* Professor of Economics, University of California at Berkeley. The author has benefited from various discussions and collaborations on this topic with Jonathan Baker, Joseph Farrell, Michael Katz and Willard Tom. Philip Nelson and Henry McFarland provided helpful comments on an earlier draft. This chapter is derived from Gilbert (2005). It emphasizes the antitrust policy implications of the relationship between competition and innovation and complements other surveys such as Kamien and Schwartz (1975, 1982), Scherer (1984), Van Cayseele (1998), Nelson et al. (2002), and Katz and Shelanski (2005).

extent that arrangements affect the development of new products or processes. Nor does this chapter deal with other related topics such as R&D joint ventures, information spillovers, network effects, standards and compatibility. Competition and R&D span many topics, and this chapter intentionally limits the scope to make the task manageable.

The enforcements actions of the Department of Justice (DOJ) and the Federal Trade Commission (FTC) reflect a belief that innovation benefits from more competitive market structures. This chapter asks whether economic theory and evidence support this view. Section 2 describes the changing role of innovation in merger policy. Section 3 reviews theoretical results linking market structure to innovation incentives and also briefly deals with the issue of diversity in R&D paths. Section 4 describes empirical studies that relate competition to R&D investments and innovative outputs. Section 5 summarizes the theoretical and empirical conclusions about the relationship between competition and innovation and offers some limited recommendations for competition policy.

2. Innovation concerns in merger policy

Merger enforcement statistics illustrate the increased importance of innovation concerns in antitrust policy. Until the mid-1990s, the DOJ and the FTC rarely mentioned innovation as a reason to challenge a merger. As shown in Table 1, from 1990 until 1994, the DOJ and the FTC alleged adverse impacts on innovation in only about 3% of all merger challenges. From 1995 to 1999, the agencies cited adverse innovation effects in 18% of merger challenges. The agencies' concerns about innovation effects continued to increase in the first part of the new century. From 2000 to 2003 the DOJ and FTC mentioned innovation effects as a reason to challenge the merger in 38% of merger challenges.

Table 1. Challenges to Mergers and Acquisitions

	Total Challenges	Challenges alleging innovation effects	
		Number	Share
DOJ			
1990-1994	64	2	3%
1995-1999	121	11	9%
2000-2003	41	17	42%
FTC			
1990-1994	71	2	3%
1995-1999	148	36	24%
2000-2003	67	24	35%
Total			
1990-1994	135	4	3%
1995-1999	269	47	18%
2000-2003	108	41	38%

*Sources: DOJ/FTC Annual Reports to Congress; Agency complaints and news releases. Years shown are fiscal years, which start on October 1. Challenges to banking mergers are excluded.

Indeed, the rapid ascent of innovation effects as a factor in merger challenges is even more dramatic than these numbers suggest. In recent years, the agencies have almost always cited innovation effects when challenging mergers in industries that involve significant investments in research and development. For example, the DOJ challenged fifteen mergers in FY 2003 and filed complaints in district courts in nine of these mergers. In six of these complaints the DOJ alleged that the merger, if allowed to proceed, would reduce innovation. The three mergers in which the DOJ did not allege innovation effects were in waste hauling, television programming, and dairies. The FTC challenged a total of twenty-one mergers in FY 2003 and issued complaints in nine cases, three of which alleged adverse effects on innovation. The affected industries were process engineering simulation software, high performance organic pigments, and pharmaceuticals, all industries with significant R&D expenditures.[1] The mergers in which the FTC did not allege innovation effects were in food processing and retailing, natural gas distribution, clinical lab testing services and the marketing (but not research, development or manufacture) of pharmaceuticals.

[1] In 2001, the ratio of R&D expenditures to net sales was 17.4% in computer systems design and related services and 7.8% in pharmaceuticals, compared to 4.1% for all industries. Source: National Science Foundation (2006), Table 26.

Admittedly, while the agencies raised innovation concerns in many mergers, innovation was central to the antitrust enforcement decision in only a very few. In the vast majority of these enforcement decisions, the transactions raised conventional concerns about adverse price impacts, and it is likely that the mergers would have been challenged without regard to innovation effects. (Gilbert and Tom, 2001) Nonetheless, these enforcement statistics show a sharply increasing tendency to incorporate innovation concerns in merger challenges by the DOJ and FTC over a period of time that has spanned both Democratic and Republican administrations.

Moreover, the antitrust authorities' concerns for innovation effects are not limited to mergers. Innovation issues were prominent in the well-publicized antitrust case charging Microsoft with monopolizing the markets for personal computer operating systems and Internet browsers. The Department of Justice and 19 states accused Microsoft of engaging in practices that excluded competition and harmed innovation. Microsoft claimed that its actions were consistent with vigorous competition that stimulated research and development of new Internet browsing technologies. After many years of legal ping-pong, the case concluded with a settlement that imposed modest restrictions on Microsoft's conduct.[2]

The agencies' concerns with innovation effects, however, remain controversial. The agencies have never proven to a court that a merger threatens innovation. That may be because only a few merger cases have been fully litigated in the past fifteen years, and those that were litigated did not highlight innovation as a reason to challenge the merger. From 1998 until 2004, only five mergers challenged by the DOJ and FTC were litigated to a final verdict.[3] Of these five cases only two were in R&D-intensive industries: SunGard Data Systems/Comdisco and Oracle/PeopleSoft. The DOJ did not allege that the merger of SunGard and Comdisco would adversely affect innovation. The DOJ included an allegation of adverse effects on innovation in its complaint to block the merger of Oracle and PeopleSoft, while Oracle argued that the merger would promote

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[2] The Microsoft case did not achieve a consensus view of the effects of market power on innovation. The Department of Justice argued that but for Microsoft's conduct, which included tying of its Internet Explorer browser to its operating system, "… continued competition on the merits between Netscape's Navigator and Microsoft's Internet Explorer would have resulted in greater innovation and the development of better products at lower prices (Complaint, U.S. v. Microsoft, U.S. District Court for the District of Columbia, Civil Action No. 98-1232). The District Court concluded that "Microsoft's anticompetitive actions trammeled the competitive process through which the computer software industry generally stimulates innovation and conduces to the optimum benefit of consumers" (Conclusions of Law, U.S. v. Microsoft, U.S. District Court for the District of Columbia, Civil Action No. 98-1232 (TPJ) at 412). The Court of Appeals found that applying a per se rule against tying of the browser and the operating system "might stunt valuable innovation" (U.S. v. Microsoft, U.S. Court of Appeals for the District of Columbia, decided June 28, 2001) and remanded the case to the District Court for further review, after which the parties settled.

[3] The five cases are Tenet Healthcare, Heinz /Beechnut, SunGard Data Systems/ Comdisco, Arch Coal, and Oracle/PeopleSoft. Another case, Northwest/Continental settled after extensive litigation.

innovation. Neither side presented a detailed analysis of innovation effects at trial. The district court was not persuaded by Oracle's innovation efficiency defense, but it did not block the merger because it held that the merger would not adversely affect price competition.[4]

The antitrust agencies' approach to innovation effects in mergers is based on the concept of innovation markets. The agencies describe innovation markets in the *DOJ/FTC Antitrust Guidelines for the Licensing of Intellectual Property,* April 6, 1995 ("IP Guidelines"), whose publication preceded the sharp increase in the share of merger enforcement actions that involved innovation effects. The IP Guidelines note that an arrangement can affect price or output in three types of markets: a market for existing goods and services; a technology market consisting of intellectual property that is licensed and its close substitutes; and an innovation market consisting of the research and development directed to particular new or improved goods or processes and the close substitutes for that research and development.[5]

A number of criticisms have been leveled at the innovation market approach. Some assert that an innovation market cannot be a valid element of an antitrust analysis because R&D is not an accepted market under Section 7 of the Clayton Act, except perhaps for R&D performed under contract.[6] Another criticism is that R&D is only an input to the production of goods and services and antitrust analysis should focus on outputs, the actual supply of future goods and services.

Technology and innovation markets are useful to the extent that they serve as analytical tools to predict changes in the price or output of goods and services. For example, suppose two firms each own a patent that describes a technology to broadcast high definition television signals. They assign the patents to a single firm, which sets the royalty and license terms for both patents. Antitrust enforcers may be concerned that the joint marketing will lead to higher prices and would analyze the combination in a technology market. The concern is not specifically about higher royalties, but rather on the price and delivery of high definition television signals to consumers. It is convenient, however, to analyze effects in the upstream technology market, just as it is convenient to analyze the effects of combinations on prices of intermediate goods, when the ultimate concern is the price and supply of final goods and services to consumers. Similarly, it can

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[4] U.S. et al, v. Oracle Corporation, Findings of fact, conclusions of law and order thereon, District Court for the Northern District of California, No C 04-0807 VRW.

[5] This concept was earlier introduced by Baxter (1984). He argued that mergers and joint ventures can affect competition in three dimensions: the market for "today's products" – the goods and services presently being offered by the participants to the merger or joint venture; the market for "tomorrow's products" – the goods and services that may be delivered if the merger or joint venture is successful; and the R&D process itself. ("The activity of research and development is also a market, and it need not be, or even resemble, the market in which today's goods and services are being delivered.")

[6] See, e.g., Hoerner (1995) and Davis (2003). For a different view, see Dahdouh and Mongoven (1996).

be convenient, albeit controversial, to analyze the effect of an arrangement on the supply of new goods and services by studying the impacts of the arrangement on R&D.

Some have argued that a superior alternative to the innovation markets approach is to use the tools of potential competition theory (e.g., Hoerner, 1995). Potential competition theory recognizes two types of harms. A merger can affect potential competition by eliminating a significant present competitive threat that constrains the behavior of the firms already in the market (harm to "perceived potential competition") or by eliminating a likely future competitor (harm to "actual potential competition"), resulting in a lost opportunity for improvement in market performance from the addition of a significant competitor. The theory of harm to perceived potential competition follows the economic theory of limit pricing, in which a firm or industry restrains its price to reduce the risk of future entry. If a merger eliminates a firm with unique advantages from entering the market, the firms in the market might be able to set a new and higher price after the merger eliminates the entry threat.

Changes in the structure of an innovation market can sometimes be likened to changes in actual potential competition, as the following example illustrates. Suppose that two firms, X and Y, are engaged in research to develop a new drug to treat type 2 diabetes and agree to merge their operations. Neither firm has a therapy to treat this disease. Each firm is a potential entrant into the market for drugs that treat type 2 diabetes. The merger eliminates one of these potential entrants and thus could result in higher prices or lower output of drugs to treat type 2 diabetes. The analysis would have to consider the likelihood that each firm would develop a successful drug if they did not merge and the competitive conditions in the market for type 2 diabetes therapies with and without the entry of new drug from each of the firms. The analysis would also have to consider possible efficiency advantages from the merger, such as improvements to their R&D programs from combining both of their activities.

As a practical matter, however, it would not be easy to evaluate competitive effects in this hypothetical merger using potential competition theory. Analysis of actual potential competition typically supposes that one of the firms is already an established supplier of the relevant good and service.[7] Here neither firm is established in the industry. Moreover, for firms that are engaged in R&D, markets for the products they are developing may not presently exist. As a further example, suppose that firms X and Y are developing new types of therapies based on stem cell technologies that have potential applications for the treatment of spinal cord injuries, for which no therapies currently exist. Potential competition theory would not directly apply to a merger of X and Y, because there is no existing relevant antitrust market in which either firm is a potential competitor. This does not mean it would be impossible to perform a potential competition analysis; it would, however, require a probabilistic analysis in which

[7] In United States v. Penn-Olin Chemical Co. 378 U.S. 158 (1964), the Supreme Court accepted a theory of perceived potential competition although neither firm was a competitor in the relevant market, but the Court has not done the same for cases involving actual potential competition. See Dahdouh and Mongoven (1996), which also discusses why potential competition theory is not a substitute for an analysis of innovation competition in many situations.

competitive effects would be evaluated under different scenarios of successful drug development, weighted by the probabilities that each scenario would occur.

Moreover, some innovation effects cannot be captured using the tools of potential competition theory. Potential competition theory would not be directly applicable to evaluate the possibility that a merger of the two firms would delay the introduction of the new drug, as opposed to changing the structure of the new market by eliminating one of the potential suppliers of the new therapy. Nor would potential competition theory have been useful in one of the first innovation market cases, when the DOJ challenged the proposed acquisition of the heavy-duty truck transmission division of ZF Friedrichshafen by GM.[8] The merger would have lessened actual price competition between GM and ZF in Europe, where the two firms were the largest suppliers, but not in the U.S., because ZF was not a significant supplier in the U.S. market. The DOJ's theory was that competition between GM and ZF in Europe propelled innovation by the two companies, and this competition would be lost if the companies merged. The merger threatened U.S. consumers with the loss of better products that GM would develop as a consequence of innovation competition in Europe and then sell in the United States.[9]

Thus, in some circumstances an innovation markets analysis can be a superior approach to analyze the effects of the merger on the performance of research and development. An innovation markets analysis, however, does not eliminate all the difficulties raised by a potential competition analysis. It is still necessary to show how the change in market structure due to the merger would adversely affect R&D and the output of goods of services.

One difficulty with innovation markets analysis is that the sources of R&D may be difficult to identify; discoveries can come from unexpected places.[10] Thus, it may be impossible to identify or measure the significance of competitors in innovation markets. The force of this objection clearly depends on the industry in question. For example, it is unlikely that within a time frame of several years, the discovery of a new gene therapy to treat macular degeneration would come from a firm that is not in some way already involved in research and development of pharmaceuticals or biotechnology.

A more fundamental problem of innovation market analysis is that economic theory does not describe an unambiguous link between the structure of R&D and the supply of new goods and services. In particular, a decrease in the number of firms engaged in R&D can accelerate the introduction of a new product and reduce its cost by making it easier for the successful firm to capture the results of the R&D program (a point made by Joseph Schumpeter, 1932 and 1946) and by eliminating redundant

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[8] United States v. General Motors, Civil Action No. 93-530 (D.D.C. 1993). See Gilbert and Sunshine (1995) for a discussion of the enforcement issues in this case.

[9] The parties abandoned the transaction.

[10] Innovations sometimes come from different industries (see, e.g., Henderson, 1993). Baker (1995) notes that market leaders innovate in some industries, while smaller competitors have been most innovative in other industries.

expenditures. R&D is an input to production, not an output, and more R&D does not necessarily imply more goods and services.[11] This issue will be considered in the next two sections.

3. Incentives for innovation under different market structures

Economic theory supports neither the view that market power generally threatens innovation by lowering the return to innovative efforts nor the Schumpeterian view that concentrated markets generally promote innovation by providing a stable platform to fund R&D and by making it easier for the firm to capture its benefits. The incentive to innovate is the increase in profit that a firm can earn if it invests in R&D. This incentive can be decomposed into several economic forces that are present to a greater or lesser degree in different market environments. The economic force underlying the Schumpeterian view is the profit that can be earned from a new product or process, which depends on the size of the innovation and the extent to which the innovation is protected from imitators. A product market that is highly concentrated after innovation (the market for "tomorrow's products", using Baxter's (1984) terminology) can reward innovation if the factors that lead to high concentration also make it difficult for others to profit by imitating the invention. A second economic force is the profit that is eliminated by an innovation. If the profit that can be earned using a legacy technology is high, as may be the case in highly concentrated product markets before innovation occurs (the market for "today's products" in Baxter's terminology), then the incentive to innovate, which is the increase in profit from the innovation, can be small.

A third force is the reduction in competition that can occur when innovation allows a firm to differentiate its products or achieve significantly lower production costs. Aghion et al. (2001, 2005) call this the "escape-the-competition effect".[12] Market structure and the incentives for R&D are simultaneously determined, as Sutton (1998) demonstrates. Firms have incentives to invest in R&D if post-innovation market competition allows them to profit from their investments, however the extent of post – innovation competition is itself determined by firms' R&D decisions. R&D that changes costs and qualities will change incentives for competition, which in turn changes incentives for firms to maintain a dominant position or to leapfrog a strong competitor. Furthermore, a firm in an oligopoly may invest in R&D not only to achieve lower production costs or produce better products, but also to change the competitive dynamic in the industry. Lower production costs can cause the innovating firm to increase its output, causing competitors to react and lower their outputs. Innovation in this situation

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[11] See, e.g., Rapp (1995), Carlton and Gertner (2003), and Katz and Shelanski (2005). Recognizing that combinations of firms may provide superior research and development, Robert Pitofsky, former Chair of the US Federal Trade Commission, proposed a narrow defense for mergers that facilitate R&D (Pitofsky, 1992).

[12] See also Boone (2001). Bonanno and Haworth (1998) examine the effects of competition on the direction of innovation.

benefits the firm both by lowering its costs and by increasing its equilibrium output. The former is a direct effect while the latter is a strategic effect on competition. In this case the strategic effect is an additional inducement to invest in a process innovation.[13]

A fourth force is the incentive to preempt competition. A firm with market power may be able to preserve its market power by innovating to deter the entry of rivals. In some circumstances, this preemption incentive can neutralize the disincentive for innovation that arises when an innovation eliminates profits earned with a legacy technology. Successful preemption, however, requires a number of conditions, including a dominant firm that can internalize most of the benefits of an investment that deters rivals.

Competition in research and development (competition in the R&D process in Baxter's terminology) has effects on the amount and timing of R&D that differ from competition in the product markets before and after innovation occurs. If the outcome of R&D is highly uncertain, then increasing the number of firms engaged in a race to patent a new innovation generally reduces the expected arrival time of the innovation.[14] Increasing the number of firms engaged in R&D may have no effect on the timing of innovation if the output of R&D is relatively predictable and if one firm is far ahead of its rivals in the race to invent (Fudenberg et al., 1983).

The complexity of the relationship between innovation and market power or market structure stems from the large number of factors that may influence the incentives to innovate and their often opposing effects. These factors depend on the nature of intellectual property protection, characteristics of the invention, the extent of competition before and after innovation, and the dynamics of R&D. Determining the overall incentive to innovate requires answering many questions, including the following:

What property rights exist to protect the invention?

Is the invention protected by patent, and if so, is the patent easy or difficult to invent around? Are there other mechanisms to protect an innovator from imitation?

What is the nature of the invention?

Is it a cost-reducing process or a new product? Is it a minor advance, or does it have the potential to disrupt the industry hierarchy? Does it complement a firm's other products? Does it require fundamentally different capabilities to make or use than currently exist in the industry?

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[13] In other examples the strategic effect can go the other way. The innovating firm may reduce its price to reflect its lower costs. Competitors may react to the lower price by reducing their prices, which would lower the net benefit from the process innovation. This strategic effect would reduce the incentive to invest in a process innovation (see Bester and Petrakis, 1993).

[14] See, e.g., Loury (1979), Dasgupta and Stiglitz (1980b), Lee and Wilde (1980), and Gilbert and Sunshine (1995).

What is the extent of competition pre-innovation and post-innovation?

Is the innovator a participant in a highly competitive market, or a firm that is largely protected from competition? Is price or product differentiation important in the industry? Are there significant barriers to R&D? Does R&D require specialized assets that are not widely available, or is it something that (almost) anyone can do? Is the inventor also the innovator, or does the inventor plan to license, sell, or assign the invention to a different entity?

What are the dynamics of R&D competition and the stochastic nature of R&D?

Although R&D is necessarily uncertain, are the outcomes of R&D programs reasonably predictable or a shot in the dark? Can firms observe and respond to rivals' R&D activities? Can firms coordinate their R&D activities to avoid redundant expenditures?

Whether an inventor can retain and exploit exclusive rights to her invention affects how other factors, such as firm size, influence the incentives to innovate. Suppose the invention is a new process that lowers a firm's variable cost of producing a good or service. The value of the invention to a firm that adopts it is the increase in profit from using the new technology. If the inventor cannot sell or license the new technology, its value is the cost reduction for the inventor's output of goods or services affected by the new process. If the firm is small, perhaps because it is one of many firms in a competitive market, its benefit from the new technology is correspondingly small. On the other hand, if the inventor can sell or license the new technology to others, the total value that the inventor may collect is the sum of the cost reductions for all the potential adopters, which, for other adopters, is independent of the inventor's own scale of operations.

Whether the inventor can sell or license its new technology is usually, though not necessarily, determined by whether the invention is protected by an exclusive intellectual property right, such as a patent. A patent confers the right to exclude others from making, using, or selling the invention claimed by the patent for the term of the patent grant. If the new technology is patented, the inventor can license one or more firms to use the new technology. In this way the patent allows the inventor to expand the universe of potential applications for the new technology and increase its value.

Patent protection does not guarantee that the inventor can prevent competition from others, either legally by inventing around the new technology, or illegally by infringing the patent. Several studies have shown that patents do not confer substantial protection in many industries (see, e.g., See Levin et al., 1985, Cohen et al., 1989b, and Hall and Ziedonis, 2001). If patent protection is weak or non-existent, the inventor may choose to keep the new technology a secret, avoiding disclosure and thereby hoping to gain a lead before others can imitate her discovery. In some cases a new discovery may require large complementary investments that raise barriers to entry for imitators and give the inventor at least some exclusivity. Licensing is not out of the question even if the invention does not have the protection of a patent. Sometimes the information required to employ a new

technology is so specialized that it requires extensive teaching from the inventor or another experienced user. That information can be shared with a know-how license. The risk of a know-how license is that the licensee may choose to use the know-how and renege on promised royalty payments after the licensee obtains the information required to use the new technology.[15] The licensor may be unable to recover damages if the licensee can use the know-how to invent around the new technology or engage in misappropriation that is difficult for the licensor to detect or enforce. However Anton and Yao (1994) show that even in the absence of patent or trade secret protection, an inventor can discourage this type of misappropriation by threatening to license the know-how to rival firms if the licensee reneges on the terms of the agreement.

3.1. Innovation incentives with non-exclusive rights

This section focuses on R&D incentives for process innovations that are protected as trade secrets or with some other intellectual property right that does not prevent independent discovery of the new technology. Inventors often choose to protect process innovations as trade secrets, because a patent discloses the invention and it is difficult to detect when someone infringes a process patent.[16] Trade secret has more limited value for product innovations because the discovery is revealed when the product is sold. The first to invent benefits only to the extent that keeping the invention a secret can provide a head start against rivals, or if the inventor is so dominant in the industry that competition from rivals can be ignored.

In this case of non-exclusive intellectual property rights, the presence of rival firms that can independently invent and adopt the new process technology reduces the value of discovery to each potential inventor. With greater numbers of firms that compete in the supply of goods or services that benefit from a new technology it is likely, though not necessary, that each firm's share of the total output using the new technology would fall and so would its corresponding benefit from invention.[17] A smaller share reduces the benefit from a process innovation because its value is proportional to the scale at which it is used. Thus, with non-exclusive rights to a process technology and profit-maximizing inventors, competition can discourage investment in R&D. This result is consistent with the view expressed by Joseph Schumpeter that large firms and, by extension, concentrated industries have greater incentives to engage in R&D because they are better able to capture its benefits.

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[15] This risk could be avoided by requiring the licensee to pay for the know-how in advance. Such a requirement imposes a risk on the licensee, however, who has to pay for the new technology before knowing what it is worth.

[16] See, e.g., Levin et al., 1987 and Cohen and Klepper (1996b).

[17] This is not a necessary result because competition lowers prices and increases total output. The increase in total output can offset the reduction in the output of each firm. See Dasgupta and Stiglitz (1980a) for a derivation of the effects under certain market assumptions.

Innovation expenditures can be redundant if an inventor cannot prevent another firm from independently investing to make the same discovery, as would be the case with non-exclusive intellectual property rights. Competition in R&D is economically inefficient if it merely duplicates an invention without introducing new features or enhancing the capabilities of firms to develop other new technologies. It would be more efficient to have a single invention and encourage its use by others, but incentives to invent would be small unless the inventor has a way to obtain compensation from others who use the invention.

With non-exclusive intellectual property rights, competition tends to reduce the incentive to invest in process R&D because competition tends to limit the output of each firm (holding other things, such as the size of the market, constant), which in turn reduces the benefit from a new cost-reducing technology. A complication is that the number of firms in a market equilibrium that will invest in R&D is itself endogenous to the production technology and to the nature of competition in the industry. Suppose that the invention lowers a firm's constant marginal production cost and that competition is so intense that only the firm with the lowest marginal cost survives in the industry. Furthermore, suppose that if two or more firms make a process innovation, then they have the same marginal cost and competition between them destroys any profit from the invention. In this case, if one firm has already developed the new technology, no rational second firm would invest in R&D. A second inventor would earn no net revenue with the new technology and would suffer the costs of R&D. The first firm to invent therefore has *effective* exclusivity, because no rational second firm would invest. Where post-entry competition is extremely intense, the exclusivity assumption is not important because competition limits the number of firms that would engage in R&D. Of course this argument presumes that firms invest rationally in R&D and that they observe whether a firm has succeeded in R&D before they invest.

3.2. Innovation incentives with exclusive rights

In some circumstances, economic theory contradicts the Schumpeterian argument that competition erodes incentives to invest in R&D for a new process technology when the inventor has exclusive rights that guarantee perpetual protection from imitators. Whether or not an inventor has exclusive rights to a new technology does not affect the incentives of a monopolist that is the only firm that can either invest in R&D or use the new technology. But exclusivity does affect R&D incentives for competing firms.

Assuming the inventor gets exclusive rights to the invention, Arrow (1962) showed that a monopolist that is not exposed to actual or potential competition has less incentive to invest in R&D than does a firm in a competitive industry. Exclusive intellectual property rights allow the inventor to capture the same benefits of the new technology whether it is a monopolist or one of many competing firms. The inventor can choose to expand its production by using the new technology itself, as a monopolist would, or license others. If the inventor and the monopolist have similar abilities to exploit the new technology, they can earn similar benefits. Even if the inventor had

inferior technical capabilities, it could extract value by licensing the new technology for use by others. Assuming that the inventor is not unduly constrained in the license fees that it may charge, the potential benefit from the invention would be similar to the benefit that a monopolist could earn.[18]

But even if the competitive firm and the monopolist realize the same profits from an innovation, the monopolist will realize a smaller net benefit. A firm that has a monopoly position in a market has a flow of profit that it enjoys if no innovation takes place. The monopolist can increase its profit by innovating, however it loses, or cannibalizes, the profits from its old technology and benefits only by the increment to its profits. Tirole (1997) calls this the replacement effect. A firm in a competitive industry, by definition, has no legacy flow of profits to cannibalize, other than the normal return on investment for a competitive industry. If the competitive firm can capture the same benefit from innovation as the monopolist, its differential return is higher because it has no monopoly profits that are replaced by the innovation. A monopolist's pre-innovation stream of profits reduces its net payoff from innovation relative to a competitive firm. Hence Arrow concludes that a monopolist has less incentive to invest in R&D than a competitive firm.

Arrow's results are instructive, but are not sufficiently general to show that competition necessarily promotes R&D for inventions that can be protected by patents. As noted above, patents rarely provide an inventor with an exclusive ability to exploit her invention and other forms of intellectual property protection, such as copyright and trade secret, are typically weaker. Even with exclusive intellectual property rights, Arrow's theoretical results do not necessarily extend to product innovations, which are significant both because they account for a large fraction of total R&D expenditures and because new products spur economic growth and advance consumer welfare.[19] When firms compete by offering differentiated products, even competitive firms can earn positive profits. Hence a competitive firm also can face a replacement effect that reduces its incentive to develop a new product, although it is likely to be smaller than for a monopolist. Furthermore, a new product changes the ability of a firm with a portfolio of products to discriminate among consumers, and this can make innovation particularly attractive for a monopolist. These factors imply that under some conditions a monopolist can benefit more from a product innovation than a competitor.[20]

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[18] License fees may be constrained because the licensor may be unable to perfectly monitor the output of the licensee, or by antitrust laws that limit the types of contracts that the licensor can employ. See Gilbert and Weinschel (2005) for a discussion of antitrust constraints on licensing agreements.

[19] The National Science Foundation estimated that in 1981 about 75 percent of all industry R&D was directed to product innovations. National Science Foundation (1981). The fraction varies for different technologies. In a survey of information technology, more than half of the respondents reported that new processes contributed most to their company's revenues. National Science Foundation (2004).

[20] See, e.g. Greenstein and Ramey (1998), describing a model of R&D competition with vertical product differentiation. For particular distributions of consumer preferences, the monopolist's ability to price discriminate using both products gives it a greater incentive to introduce the new

Relative investment incentives in monopoly and competitive markets are, however, similar for process and product innovations protected by exclusive and permanent rights when the innovations are "drastic". Innovations are drastic if existing products or processes do not constrain the inventor's profit-maximizing price. A drastic product innovation makes existing products obsolete. With exclusive rights, the payoff from a drastic innovation is the same for both monopoly and competitive firms, but the replacement effect is lower for a competitive firm. Incumbent firms that are protected from product market and R&D competition have lower incentives to invest in R&D for new products or processes that are drastic innovations, compared to firms in competitive markets. This result helps to explain Christensen's (1997) observation that dominant firms tend to introduce incremental improvements, while drastic discoveries tend to come from new competitors or fringe firms.

3.3. Preemptive investment in R&D

Arrow's result that, with exclusive intellectual property rights, competition leads to more research and development than monopoly will not hold in all cases, even for process innovations. For example, a monopolist that is already entrenched in a market may have incentives to invest in R&D to preempt competitors. Arrow's analysis assumed that a monopolist faced no competition in either the product market or in research and development. A firm may have an entrenched position in an existing product market resulting from, for example, large sunk assets, strong brand recognition, or large complementary investments that give rise to network economies. But even an entrenched monopolist faces the risk that a new discovery will be introduced that will compete with its established product or a new process will confer a cost advantage on a competitor. A monopolist has incentives to invent new products or processes itself, thereby preempting potential rivals. Gilbert and Newbery (1982) show this incentive to preempt may be stronger than Arrow's replacement effect. Thus, a monopolist can have a greater incentive to invent than a competitive firm, provided that the monopolist can forestall competition by innovating. The monopolist's incentive to make the next discovery is the profit that it would lose if a competitor successfully enters the industry. A competitor's incentive to invent is the profit it would earn if it successfully enters. Under some conditions, the monopoly's incentive to preserve its profit can exceed the competitor's profit incentive and the monopolist may invest heavily to preempt entry by being the first to patent a new technology.

The implications of preemptive investment for consumer welfare are complex. The practice will extend the life of a monopoly, but not indefinitely. Society is likely to benefit from faster introduction of new products. In some cases, a monopolist may take a sleeping patent, that is it may patent a product but not introduce it to the market. That

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product than a new competitor who sells only the new product. Similar results can be obtained with a model in which firms supply products that are horizontally differentiated, meaning that consumers differ in their preferences for products sold at the same price. See, e.g., Gilbert (2005).

behavior, however, is likely to be rare, both because the inventor would forego the benefits of the new technology and because other innovators are likely to invent around the patent. A firm may also engage in preemptive R&D in a race to develop a new product. The incentives for such preemption stem from the dynamics of innovation competition. In a race to be the first to gain exclusive rights to a new product a firm that has a head start in the R&D competition may be able to maintain its lead over rivals. If any rival attempts to close the technology gap, the leader may engage in preemptive R&D to maintain its position. Knowing that their efforts will be futile, rival firms that lag in the R&D competition may drop out of the race entirely. Preemption can occur if the dynamics of R&D competition provide a technological leader with an unassailable position in a race to patent a new technology. In some circumstances, a small lead in the innovation race can be enough to render competition ineffective, and adding more competitors to the R&D race may have little or no effect on the pace of innovation by the firm that occupies the technological frontier.[21]

Preemption results typically rest on several strong assumptions. A firm can preempt competitors by investing in R&D only if it can obtain rights to an invention that effectively foreclose alternative entry paths for competitors. In most markets, firms can take many paths to develop new technological alternatives and closing one path (e.g., by winning a patent) is not likely to erect an insurmountable obstacle to new competition. A preemption strategy may not be profitable if the incumbent firm is not a monopolist (Vickers, 1985). Competition reduces the payoff to a preemption strategy, because the benefits from preventing competition are shared with others. For an effective preemption strategy, a firm must be confident that it will win the R&D competition if it invests more than its rivals or if it achieves a head start in an R&D race. As Reinganum (1983,1989) has shown, uncertainty in the link between rival firms' investments and their R&D success can undermine preemption incentives. An incumbent firm has no incentive to preempt its rivals if there is a large enough probability that its rivals' R&D efforts will fail. Furthermore, the preemption result assumes that an entrant that wins a patent cannot bargain with the incumbent for exclusive rights to the new technology (Salant, 1984). Bargaining allows an innovator to obtain a share of the incumbent's monopoly profit. This increases a competitor's expected profit from innovation and makes it more expensive for the incumbent to preempt entry. These conditions that are necessary for successful preemption are restrictive, and the preemption incentive is unlikely to dominate the replacement effect for most R&D-intensive industries.

3.4. R&D diversity

Competition may spur innovation not only by leading to more R&D but also by leading to more diverse R&D. Parallel R&D paths can contribute value to the extent that the paths are not redundant. Anecdotal evidence suggests that organizational factors limit the extent to which a firm can diversify its innovation efforts. Andrew Grove, the former CEO of Intel, described how he wanted to keep his options open by pursuing active R&D

[21] See, e.g., Fudenberg et al. (1983) and Harris and Vickers (1985).

programs for microprocessors that utilized both RISC (Reduced Instruction Set Computing) and CISC (Complex Instruction Set Computing) technology. In the end, Intel abandoned RISC in favor of CISC because it was too difficult to pursue both options simultaneously. (Grove, 1996)

The preservation of alternative R&D paths was an important factor in the DOJ's decision to challenge the proposed merger of Lockheed and Northrop.[22] Lockheed and Northrop compete to develop, manufacture and sell a range of electronics systems and military aircraft to the U.S. military. Although many of the markets in which Lockheed and Northrop compete are highly concentrated and have high barriers to entry, according to Rubinfeld and Hoven (2001), " the cornerstone of the challenge [to the merger] was concern that the acquisition would substantially lessen innovation in various products and services for defense applications."[23] Focusing on the market for high-performance fixed-wing aircraft, Rubinfeld and Hoven note that "the issue was not whether a consolidation from three aircraft manufacturers to two would reduce the intensity of innovative effort. The published literature does not yield a clear conclusion on that, especially since a large share of R&D spending is funded by the DOD. Rather, the issue was that the number of independent innovators would be reduced by one. . ." The DOJ Director of Operations and Merger Enforcement echoed the importance of innovation in the DOJ's decision to challenge the Lockheed/Northrop merger and emphasized the need to maintain diversity in the core capabilities to develop and produce advanced military systems.[24]

Unfortunately, little is known about the effects of competition on innovation diversity. It is not obvious that reducing the number of firms in an industry reduces the number of independent R&D paths. That follows if each firm takes a single R&D path, but some firms successfully pursue several research paths. For example, pharmaceutical research companies test hundreds and thousands of molecular combinations in search of new medicines.[25] Some theoretical work suggests that competition can result in too much innovation diversity, as firms attempt to differentiate their research activities in order to minimize competition.[26]

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[22] U.S. Department of Justice v. Lockheed Martin and Northrop Grumman, Complaint, U.S. District Court for the District of Columbia, March 23, 1998. (available at http://www.usdoj.gov/atr/cases/f1600/1609.htm).

[23] Daniel L. Rubinfeld and John Hoven, "Innovation And Antitrust Enforcement," January 19, 1999 working paper. Rubinfeld was Chief Economist and Hoven was staff economist at the DOJ during the investigation of the proposed Lockheed-Northrop merger.

[24] Constance K. Robinson, "Leap-Frog And Other Forms Of Innovation: Protecting the Future for High-Tech and Emerging Industries Through Merger Enforcement," speech before the American Bar Association, Chicago, Illinois, June 10, 1999.(available at http://www.usdoj.gov/atr/public/speeches/2482.htm).

[25] See, e.g., Henderson and Cockburn (1996). (larger pharmaceutical companies realize economies of scope by sustaining diverse portfolios of research projects that capture internal and external knowledge spillovers)

[26] See, e.g., Dasgupta and Maskin (1987) and Farrell et al. (2003).

3.5. Managerial incentives for R&D

A feature that is absent from the standard economic analysis is that people perform R&D, and people have whims and preferences that are often in conflict with the goal of profit-maximization. Sir John Hicks observed that monopolies are slow to innovate when he said that "The best of all monopoly profits is a quiet life" (Hicks, 1935). Perhaps competition promotes R&D, not because innovation is more profitable in competitive markets, but rather because competition disciplines firm managers in ways that promote innovative activity.

Several theoretical papers show that even with non-exclusive intellectual property rights, competition can stimulate R&D by forcing managers to innovate in order to reduce the risk of bankruptcy. (See, e.g., Schmidt, 1997 and Aghion et al., 1999). If the risk of bankruptcy is low in monopolistic markets, the need to innovate is also low and managers of monopoly firms can enjoy the quiet life. However, even these models do not provide a robust conclusion that competition promotes innovation. Managers could have a fascination with new technologies and invest too much in R&D. In this case the risk of bankruptcy, which is greater in competitive markets, would encourage managers to be more efficient by being less innovative. The general result is that competition reduces the margin that managers enjoy to pursue their own objectives, and this can move them in the direction of more or less R&D. The effects of competition on managerial performance also depend on whether firms are active in credit markets. Managers may have to act efficiently to avoid bankruptcy if their firms are saddled with debt, because a high debt load, even for a firm with market power, squeezes the margin available to managers to pursue objectives that are inconsistent with profit-maximization.

4. Empirical studies

The theory leaves significant gaps in our understanding of the effects of market structure on innovation, and hence it is all the more important to turn to empirical studies. Unfortunately, although many studies test the hypothesis that market structure influences research and development, most have serious deficiencies that greatly undermine their value. Early studies often failed to account for industry differences in technological opportunities and in the ability of firms to capture the value of their inventions. Moreover, many studies examine the effects of market structure on R&D spending, but R&D spending is an input to the innovation process, not an output of innovation. Some studies attempt to measure the output of innovation by counting patents, but patents are only weakly related to actual innovation performance. This section offers a brief review of the vast empirical literature relating R&D expenditures and innovation to market characteristics such as concentration, competition and firm size.

4.1. Market structure and R&D intensity

Using Federal Trade Commission 1974 line of business data for 437 firms, Scott (1984, 1993) found no significant relationship between market structure and R&D intensity after controlling for effects that were specific to firms and their industries. Also using FTC line of business data, Levin et al. (1985) show a statistically significant relationship between industry concentration and both R&D intensity and the rate of introductions of innovations that peaked when the combined market share of the largest four firms in the industry was about fifty percent to sixty percent. The authors then included variables to measure technological opportunity and appropriability for each firm. These included, for example, the effectiveness of appropriation mechanisms such as secrecy, lead time, and ease of imitation. Inclusion of these variables dramatically lowered the significance of the concentration variables in the R&D regression. At the same time, technological opportunity and appropriability were significant, with the expected signs. These inter-industry econometric studies suggest that whatever relationship exists at a general economy-wide level between industry structure and R&D is masked by differences across industries in technological opportunities, demand, and the appropriability of inventions, all of which are important to the process of innovation. As Baldwin and Scott (1987) note, "The most common feature of the few R&D and innovation analyses that have sought to control for the underlying technological environment is a dramatic reduction in the observed impact of the Schumpeterian size and market power variables."

Cross-sectional statistical studies do not allow a strong test of the relationship, if any, between competition and R&D because it is extremely difficult to hold other factors constant that influence innovative activity.[27] An ideal test of the effect of competition on innovation would be a "natural experiment" in which external and unforeseen events cause a discrete change in competition with no other consequence for other determinants of innovation, such as technological opportunity or appropriability. Unfortunately, there are no examples in the economics literature of a true natural experiment to study the effect of competition on innovation. Still, some studies have gotten useful results by focusing on market events that are close to the appropriate experiment.

Changes in import policies, which cause relatively rapid changes in market structure without changing technological opportunities, are plausible albeit highly imperfect approximations of natural experiments. Significant increases in competition resulting from changes in import penetration or other industry shocks have triggered the major restructuring of some industries to achieve lower manufacturing costs and to develop new and more competitive products.[28] MacDonald (1994) confirmed these observations by analyzing the determinants of the rate of growth of labor productivity (output per hour of labor) in 94 industries during the period 1972 through 1987. He

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[27] Porter (1990) observes that competitive markets have more innovation, but his conclusions are based on international comparisons that do not control for other possibly confounding factors.

[28] See, e.g., Dertouzos (1990) (describing the experience of Xerox, domestic steel and chemical producers, and commercial airline manufacturers to increased competition).

found that increases in import penetration had large positive impacts on labor productivity in highly concentrated industries. Using labor productivity as an imperfect indicator of technical change, these results suggest that a sudden increase in competition had significant benefits for technical progress in markets that had been highly concentrated.

A study by Bresnahan (1985) reported on the consequences of an FTC consent decree that opened a market to new competition. In 1975, the Federal Trade Commission reached a consent decree with the Xerox Corporation that required Xerox to offer non-exclusive licenses at prescribed royalties for all of its patents relating to plain paper copiers. The FTC order generated a discrete change in the structure of the plain paper copier industry. There was a sudden entry of new competitors who previously were foreclosed from competing in this industry because they did not have access to the Xerox patent portfolio. Xerox's share of all plain paper copiers in use fell from 100 percent in the early 1970s to about 45 percent by the mid 1980s. There was a great deal of innovative activity over this time period by both Xerox and new entrants into the plain paper copier industry. Changes in technological opportunities in the post-consent decree time period, such as the invention of the microprocessor, make it difficult to draw a confident conclusion that the surge in innovation was a direct result of the increase in competition brought about by the consent decree. Instead, Bresnahan focused on the direction of innovation in the post-consent decree period. Bresnahan found that most firms entered market niches that were not close substitutes for their existing product lines. For example, producers of coated paper copiers (such as SCM, A.B. Dick, and Royal) moved into high-speed plain paper copiers, even though they possessed marketing and distribution expertise that would have been particularly useful in the small-volume copier segment. Many of the new entrants into the low-volume copier segment were firms that had no prior experience in the copying industry (such as Savin and Ricoh). Xerox continued to offer products for all market segments. Bresnahan (1985) concluded that "…firms that had a choice chose to enter product segments where higher rates of inventive activity would destroy others' rents, not their own." This behavior is consistent with innovation incentives that follow from the Arrow replacement effect.

4.2. Empirical evidence concerning preemption

There is little empirical evidence that established firms invest heavily in R&D to preempt competitors. Even in the pharmaceutical industry, where patents provide strong protection from imitation, the patenting of a new drug need not prevent other firms from developing and patenting other drugs that have similar therapeutic effects (Cockburn and Henderson, 1995). Lerner (1997) studied personal disk drives, an industry characterized by a sequence of transforming innovations. He found that the firms that were the market leaders in a particular generation of disk drive technology often failed to maintain their lead in the next generation. Dominant firms in this industry were not able to preempt future competition. Blundell et al. (1995, 1999) find evidence that dominant firms tend to innovate more, which is consistent with preemption, but they also conclude that overall market concentration depresses innovation. Czarnitzki and Kraft (2005) find empirical evidence for the proposition that dominant firms are more likely than smaller firms in an industry to acquire exclusive licenses for new technologies. This is consistent with the preemption theory, but it applies to a bidding market in which the prerequisites of the theory are

more likely to be satisfied.

4.3. Empirical Evidence Concerning Firm Size and R&D Intensity

Given differences in market sizes, the relationship between market structure and firm size is far from perfect, and firm size can have implications for R&D investment that are distinct from market structure effects. Kamien and Schwartz (1982), in their review of the early empirical literature, concluded that "R&D activity, measured by either input or output intensity, appears to increase with firm size up to a point and then level off or decline…"(p. 103) A constant R&D intensity implies that R&D increases proportionally with firm size. Baldwin and Scott (1987), summarizing many studies, conclude that: "the preponderance of evidence ... indicates that economies of scale in industrial R&D, of both the firm and the research establishment, are in most cases exhausted well below the largest firm and research establishment size examined. The studies that have found a pervasive positive relationship between size and R&D intensity are those drawing on samples including companies of widely ranging sizes and with little or no control for industry effects ... The Schumpeterian hypothesis relating innovation to firm size appears to hold up if interpreted as a threshold one, but does not imply that giant corporations are essential for vigorous R&D in most fields." (p.87)

Economic theory suggests that the effects of firm size and competition on innovation should differ for process and product innovations. Process innovations are more difficult to protect from imitation, even if they are patented, because infringement often cannot be detected. For this reason intellectual property protection for process innovations has more of the characteristic of a non-exclusive intellectual property right. Many empirical studies of market structure and R&D failed to distinguish product and process innovations, which is a serious deficiency.

The few empirical studies that have separately tracked research and development for new products and processes have identified effects that agree with the theoretical prediction that the return to investment in process R&D increases with the scale of output that employs the process. For example, Link and Lunn (1984) found that returns to process R&D increased with market concentration for process innovations. While Link and Lunn looked at concentration, because they did not control for firm size, they may have found a firm size effect. All else equal, higher market concentration suggests greater scale.

More recent studies find additional and sharper support for the theory. Cohen and Klepper (1996a) find that business unit size explains most of the variance in process R&D expenditures and that sales at the firm level have virtually no additional explanatory power. This result is consistent with the theoretical argument that the value of a process innovation that is not licensed or sold to others should be proportional to the output of the activity to which it is applied. This output is related to the size of the business unit in which the process is used, not necessarily to the total size of the firm.

Cohen and Klepper also find that the relationship between R&D expenditure and business unit size is weaker in industries that experience high growth or where licensing of innovations is common. These factors allow even a small firm to benefit from R&D, either by licensing the innovation to others or by applying the innovation to higher future output. Cohen and Klepper (1996b) test the relationship between firm size and the propensity of firms to patent product and process innovations. Following Scherer (1982), they assume that a patent covers a process innovation if it is employed in the same industry in which it originates, the argument being that innovations that are kept in-house are likely to relate to productive efficiency rather than to new products for sales to others. They find that the fraction of patents that are classified as process innovations tends to increase with the size of the firm. This is also consistent with the theory, as larger operations allow a firm to benefit more from a process innovation.

4.4. Summary of Empirical Findings

These empirical observations have important implications for the Schumpeterian hypothesis that large firms and market power promote R&D. Schumpeter argued that a monopolist can more fully exploit economies of scale in R&D and monopoly profits can cushion the uncertain payoff of R&D. Furthermore, most firms finance R&D with internally generated funds, so monopoly profits can translate into more dollars to spend on R&D. Firms are likely to know more than investors about R&D prospects. Investors would be reluctant to invest in risky R&D projects if they believe that firms will use internally generated funds for projects that have high expected payoffs and will turn to the capital market only for projects that have low expected or unusually risky payoffs. This raises the possibility that monopoly is beneficial for R&D simply because monopoly profits lower the cost of raising funds for R&D. However, the finding that process R&D is proportional to business unit size, but not firm size, contradicts the argument that monopoly promotes innovation by providing a more stable platform to engage in R&D.

It is important to recognize that these empirical results relate to R&D spending and not to the output of innovation. The results suggest that, at least for process innovations, R&D expenditures increase in proportion to firm size, above some threshold level. This implies that, all else equal, a merger would not increase the total level of R&D spending in an industry. However, such a merger could increase the output of innovation and reduce the extent of redundant R&D effort. With non-exclusive intellectual property rights the investment in R&D by each firm in a fragmented industry may be quite small, corresponding to its relatively small output, and the level of cost reduction for each firm achieved by that R&D investment also would be small. By increasing a firm's output, a merger could generate greater incentives for investment in process R&D and a greater cost reduction for the industry. Thus these empirical results suggest that, at least for some types of process innovations, industry consolidation could benefit the output of cost-reducing innovation and be a partial efficiency defense to mergers that may otherwise raise prices.

5. Concluding Remarks

This chapter surveys economic theory and empirical studies on the relation between horizontal market structure and incentives to invest in process and product innovation. The incentive to invest in R&D increases with the monopoly profits that a firm can protect by innovating and decreases with the profits that a firm can earn if it does not innovate. Innovation incentives differ for inventions that are protected by exclusive and non-exclusive intellectual property rights, as non-exclusive property rights imply greater post-innovation competition and lower profits from innovation.

Arrow (1962) showed that for process innovations that reduce marginal production costs, innovation incentives are lower for a monopoly that is protected from both product and R&D competition than for a competitive firm, provided that the innovator maintains exclusive and permanent rights to the innovation. This result does not necessarily extend to product innovations. A monopolist that is protected from both product and R&D competition could have a greater incentive than a competitive firm to invest in product innovation. Relative investment incentives in monopoly and competitive markets are, however, similar for process and product innovations protected by exclusive and permanent rights when the innovations are drastic, in the sense that they make existing products or processes obsolete.

Allowing for competition in R&D can reverse Arrow's (1962) theoretical result that, given permanent and exclusive intellectual property rights, incumbents who are protected from product market competition have lower incentives than competitive firms to introduce non-drastic process innovations. Under some conditions, a firm that is a dominant supplier of an existing product has an incentive to preempt rivals by investing more in R&D than the rivals would gain from the innovation. Furthermore, a firm that has a large head start in R&D could have an incentive to maintain its lead over rivals, and that incentive could be sufficient to deter innovation competition.

While it is difficult to make general conclusions about R&D incentives in different market structures, the analysis does permit some broad characterizations and lessons for antitrust policy for R&D intensive industries. Economic theory supports the proposition that competition is more likely to provide greater incentives for product and process innovations if the following conditions apply. These conditions apply for investment in R&D with and without exclusive rights to inventions, although there is a stronger presumption that competition promotes investment in R&D if the inventor gains exclusive rights.

Competition in the old product is intense.

To the extent that competition in the old product is intense, this lowers the pre-innovation profit for a competitor that would be replaced by the new technology and increases its incentive to invent.

The innovation is a major improvement.

If the new product is such a major improvement relative to existing products that it would make the existing product obsolete, the competitor's lower replacement effect would give it a larger incentive to invest in R&D for the new product. Even without exclusive intellectual property protection, a competitor would have an incentive to invest in R&D for a major improvement, provided that it has a head start or some other protection from rapid imitation.

The innovation does not increase the ability of the monopolist to price discriminate among consumers.

A new product can be particularly valuable for a monopolist if it enables the firm to price discriminate among consumers by offering both its old and new products. If such price discrimination is not likely, the replacement effect suggests that a competitor would have a greater incentive to invest in R&D. A competitor and a monopolist would not have different abilities to price discriminate if the new product is a major improvement relative to the existing product and is protected by exclusive and effectively permanent intellectual property rights.

Market conditions make preemption unlikely.

The preemption incentive requires strong conditions and is unlikely to be significant if the incumbent firm faces product market competition or if there are alternative R&D paths that the incumbent firm cannot foreclose by patenting a new technology. Moreover, a head start in R&D is unlikely to preempt rivals if discovery is uncertain or if discovery does not foreclose alternative R&D paths. Empirical evidence for preemptive R&D investment by dominant firms is weak.

Although empirical evidence on the relationship of competition and innovation is mixed, several careful studies suggest that competition promotes innovation if inventors gain exclusive rights to their inventions. A number of studies that focus on product innovations show that R&D and competition are positively related. The relationship between competition and process innovations is different because intellectual property protection is weaker for process innovations compared to product innovations. Most inventors choose trade secret rather than patents to protect process innovations, because a patent would disclose the invention and infringement is difficult to detect and punish. If a process innovation is not licensed, it would apply to output the firm itself produces; hence the larger the firm's output, the greater the incentives for investment in R&D. Competition can reduce incentives for process innovation by reducing firm size. Empirical evidence suggests that investment in R&D for process innovations is proportional to business unit size, a result that is consistent with the theory.

Some have interpreted the result that investment in R&D is proportional to business unit size to imply that mergers or other consolidations of business activity would have no significant effect on the total amount of industry R&D. Holding the level of industry output constant, R&D will be the same with one large firm as with many small ones. This conclusion ignores the crucial distinction between R&D expenditure and the

output of innovation. If the output of process innovation is proportional to the level of R&D investment, there would be larger cost reductions if one firm performs all the R&D and applies the resulting process improvements to the entire industry output. Thus the theory and the empirical evidence suggest a plausible efficiencies defense for mergers in industries where process innovation is particularly important. Of course, a merger or industry consolidation could increase market power and result in higher prices and lower output, possibly offsetting any positive efficiency consequences from greater incentives to invest in cost-reducing innovation.

The large body of economic theory and empirical studies on the relationship between competition and innovation fails to provide general support for the Schumpeterian hypothesis that monopoly promotes either investment in R&D or the output of innovation. The theoretical and empirical evidence also does not support a strong conclusion that competition is uniformly a stimulus to innovation. While specific industry characteristics and technological opportunities determine the equilibrium relationship between market structure and innovation, there are conditions that warrant a presumption that competition promotes innovation. Under these conditions, the theory and empirical evidence support the antitrust enforcement agencies' efforts to promote innovation by challenging mergers that would harm product market competition. However, there are also circumstances for which it reasonable to assume that competition does not affect or possibly reduces innovation incentives. While harm to innovation can be an additional reason to challenge mergers, under some circumstances benefits to innovation can also be an efficiency defense to permit mergers that would otherwise result in troublesome increases in market concentration. Determining the effects of a merger on innovation will require a detailed analysis of the specific facts of each case.

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