R&D Investments, Information and Strategy

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Abstract

This paper argues that firms can best realize the value of their investments in R&D by exploiting the associated information asymmetries. Attention is directed away from the physical results of R&D and towards the firm's ability, more generally, to earn rents from the private information emanating from its R&D. Four strategies may be used to exploit the information asymmetries from R&D: (1) publish the details of the innovation in return for legal protection; (2) keep the information inside the firm; (3) make the information selectively, informally available to others; and (4) disseminate the information as widely and rapidly as possible. To implement these strategies, resources may be allocated both to the commercial development of new technologies, and/or to related market opportunities (investing in other companies, assets and technologies). This perspective should yield new insights to managers in designing strategies (and counter-strategies) to position themselves not only at the technological edge, but more fundamentally, at the 'information edge'.

Keywords: R&D investments, information, strategy, asymmetric information, international R&D management

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1 Introduction

How can firms best realize the value of their investments in research and development? In this paper, it is suggested that the answer lies not only in their ability to develop new products and processes *per se*, but more fundamentally, in their ability to exploit strategically the associated information asymmetries. Information asymmetries are defined, in this context, as arising due to differentials in the kinds of information emanating from the firm's various R&D activities, where the information generated is initially private to that firm – and hence not available to others.[1]

Firms can earn rents from the information asymmetries arising from investments in R&D by the use of four basic, and partially overlapping, strategies: (1) publish the details of the innovation in return for legal protection (patents, copyrights, and the like), (2) keep the information inside the firm (secrecy, tacit and firm-specific knowledge), (3) make the information selectively available to others on an informal basis, and (4) widely disseminate the information, making it freely accessible to all comers. These strategies may be combined, developed and changed.

To implement these strategies, resources may be allocated in two ways. First, firms may use private R&D information to develop new products and processes. This might take the form of internal research, a joint venture, or a plan to come 'second on the market'. Alternatively, firms can allocate resources to related market opportunities by investing in other companies, assets and technologies. The use of private R&D information, for example, could be critical to the direct purchase of another, undervalued innovative firm with a complimentary research programme.

The information asymmetries emanating from investments in R&D can generate rents in numerous ways. These include launching a breakthrough technology, introducing marginal variations on existing products, utilizing one's own expertise to evaluate the research results of others, trading knowledge to gain access to a technology network, signalling an interest in a potential R&D co-operation, or 'marking off' particular product markets as reserved for one's own future use. Every strategy is vulnerable to counter-strategies. Patents can be infringed, secrets can be broken, information-sharing can be abused. Thus the innovator's choice of strategy is contingent on the counter-strategies pursued by other market participants: competitors, specialists in complementary technologies, suppliers, distributors, and users. It is the outcome of this dynamic, complex interaction that determines the ultimate value of R&D investments, along with who benefits.

While there is an enormous literature on R&D incentives, and the implications of asymmetric information for competitive strategy, no-one, to my knowledge, has utilized asymmetric information in the manner described here to explore how firms can profit from their investments in R&D. It is the purpose of this paper to suggest the preliminary outlines for such a framework for analysis. It can help to explain why some new information is diffused quickly, some quite slowly, and some not at all - and why many firms may find it to their

[1] Asymmetric information can be further specified as follows: there are differences in the types of information held by the economic agents concerned; the information can be available, but when it is available it is unevenly distributed, and the differences in the information sets held by each agent are unobservable.

benefit deliberately to 'give away' research results. It can further our understanding of why firms, despite the costs and risks of innovation, continue to increase their investments in R&D.

The paper is organized as follows. Section 2 discusses the relevance of asymmetric information for the analysis of innovation and business strategy. Differences in the types of information emanating from R&D form the subject of Section 3. Following this, the four main strategies by which firms can exploit the information asymmetries arising from investments in R&D are set forth. Section 5 investigates how firms can earn rents both through developing new technologies, and exploiting related market opportunities. Section 6 expands the analysis is expanded to issues of strategy and counter-strategy, and Section 7 focuses on MNE organizational advantages. Section 8 presents the conclusion further implications for research.

2 Theoretical Background

Asymmetric information may arise both within firms (between headquarters and subsidiary, between different departments in the same division, between managers and employees, and so forth), and between them (between buyers and suppliers/distributors, and between competitors). This paper will largely be confined to the strategic implications of asymmetric information between competitors. The arguments are grounded, first and foremost, in the logic of the literature on business strategy and competitive advantage, but with a specific focus on investments in R&D.

Asymmetric information is a key concept in game theory (cf. Fudenberg and Tirole, 1991), agency theory (cf. Sappington, 1991), transaction costs economics (Williamson, 1985) and theories of property rights/corporate governance (Alchian and Demsetz, 1972). In the economics of information/industrial organization literature, the relationship between innovation and asymmetric information has been explored, for example, in the analysis of optimal R&D investment strategies (McGahan, 1993), patent races (Gilbert and Newbery, 1982), and patent licensing (Beggs, 1992). These models, however, are difficult to apply to practical business decision-making.

In the business strategy literature, R&D is viewed primarily as a means of generating competitive asymmetries between firms (cf. Lieberman and Montgomery, 1988), but not specifically as a source of information asymmetries. Students of technological innovation have explored questions such as the sources of innovation, and how innovation contributes to growth and competitive advantage – though not in the context of information asymmetry. Asymmetric information, for its part, is seen as a cause of market failure that can enhance competitiveness (cf. Yao, 1988, Nayyar, 1990) – but without an explicit linkage to R&D.

Rosenberg (1990) touched indirectly on this issue. Asking why firms engage in basic research, he contended that in many industries, firms can still benefit from investing in R&D even though the commercial gains might not be immediately forthcoming. Innovators at the technological edge cannot afford *not* to invest in R&D, for unless they maintain a certain level of in-house expertise, they cannot remain market leaders. Cohen and Levinthal (1989) found that while R&D obviously leads to innovation, it also contributes to the firm's ability to identify, assimilate, and exploit knowledge from its environment. Even if a competitor should gain access to the innovator's knowledge, it might not be able to exploit it. Only by performing its own R&D can a firm develop the requisite learning and 'absorptive capacity.' Macdonald (1998) has developed an explicit information perspective on innovation, emphasizing the key (but often unrecognized) role of informal information in R&D. But again, these scholars have not seen innovation specifically as a source of information asymmetries.

The arguments developed in this paper are novel in the following manners. First, attention is directed away from the physical results of R&D activities and towards the ability of the firm, more generally, to earn rents based on the information asymmetries arising from its investments in R&D. While there is a jointness between the physical results of R&D and the associated rents (making analytical separation of the two difficult), it is not inconceivable that an R&D programme, while producing no directly valuable commercial technology, might still yield private information enabling the firm to extract rents through exploiting a related market opportunity.

Second, the generation of asymmetric information is seen in dynamic terms. The innovative firm creates new information which, at least at first, is not known to other market agents. But it is unlikely to remain private for long. Since information is intangible, and often easily replicable and transferable, any initial asymmetries may quickly be eroded. But since innovation is also dynamic, further asymmetries will continue to emerge, as other firms produce their own new, private information.

Third, a distinction is drawn between private information, the physical results of R&D (i.e. the creation of new products and processes), and the sources of rents from R&D. The physical results of R&D may or may not have a commercial application, but will always yield private information. Some of this private information – either jointly with the physical results of R&D, or by itself – may contribute to a strategy by which the firm can extract rents. In some instances, the information must initially remain private (as, for example, in the case of speculation). In other instances, depending on the institutional context, rents may be augmented by the firm revealing all or a part of its private information. This would be true, say, of patenting – assuming a regime of strong and enforceable patent rights.

Fourth, this perspective provides another explanation of how MNEs can use their organizational advantages to achieve competitive advantage. Locating subsidiaries in many different countries enables the MNE not only to exploit a range of subsidiary-specific advantages in R&D, but also to place information-gathering 'outposts' around the world. The key organization task here is to plan the R&D effort so as to maximize the rents that may accrue from working across different countries.

And finally, the investigation of the exploitation of asymmetric information leads to a better appreciation of firm 'positioning' strategies *vis-à-vis* their own – and their rivals' – R&D efforts.

3 Informational Aspects of R&D Investments

In the economics and business literature dealing with the commercial development of new products and processes, it has long been realized that information is imperfectly appropriable. If firms cannot appropriate the rents from their investments in R&D, they will lack the incentive to invest in further research (Arrow, 1962, Nelson, 1959). The innovating firm provides a positive externality to other market participants in that due to the public good nature of information (and assuming zero transaction costs), its research results will become available to others at little or no extra cost, enabling them to 'free ride' on its benefits.

Nevertheless, empirical studies of the patent system revealed that there could be considerable industry and other differences in this regard. Mansfield and his colleagues (1981, 1986) determined that patents raise imitation costs and times only marginally for most industrial sectors – with the notable exception of chemicals and, in particular, pharmaceuticals. In a study measuring the speed at which new technological information 'leaks out' to other firms, Mansfield (1985) ascertained that in some cases, the decision to develop a new technology was known to rivals within six months; in other cases, it took longer than eighteen months. Information about new products tended to leak out more rapidly than that concerning new processes.

In the business strategy literature, it has also been recognized that new knowledge may be quickly – and often involuntarily – disseminated (cf. Zander, 1991). Studies of firm strategies of appropriability (Levin *et al.*, 1987, Bertin and Wyatt, 1988, Davis, 1988) underlined the general lack of effectiveness of the different methods, which can include patents, secrecy, lead time/learning curve, trademarks, licensing, and the like. Like Mansfield, they found striking industry variations.

The economics and business literature dealing with firm use of private R&D information to exploit related market opportunities probably also has its thematic beginnings in the debate over appropriability and the desirability of a patent system. What are, in welfare economic terms, the pecuniary effects of access to superior R&D information ('wealth redistributions due to price revaluations'), were first highlighted by Hirschleifer (1971). Hirschleifer, while recognizing the importance of the problem of appropriability, noted that these possible pecuniary effects – which could be realized due to the innovator's foreknowledge of market opportunities – represented an important force operating in the opposite direction.

To illustrate his point, Hirschleifer suggested that when Eli Whitney patented the cotton gin in 1794, he devoted much effort to trying to protect his patent and prosecute infringements, largely to no avail. Yet there were other routes to profit for Whitney. The wider adoption of the cotton gin clearly had implications for factors such as the price of cotton, the value of cotton-bearing land, the prospects of businesses engaged in cotton warehousing and shipping, the site values of key points along the transportation routes, and developments in competing industries like wool and complementary ones like textiles and machinery. Thus huge speculative gains were potentially available to anyone with foreknowledge of the coming of the cotton gin.

Few scholars have developed Hirschleifer's insights, or elaborated them in terms of the possible rents that might accrue even to firms whose immediate commercial research is otherwise a failure. Rosenberg (1990), Cohen and Levinthal (1989), and Macdonald, as noted in Section 2, explored some of the relevant issues in this respect, but did not explicitly analyze R&D investments as a source of information asymmetries.

The classic work on strategy and counter-strategy as regards profiting from investments in R&D is Teece (1986). He pointed out that innovators often fail to win from investments in innovation, while customers, imitators, suppliers and other market participants benefit. Some industries could be characterized by a 'tight' appropriability regime, where patents and related methods effectively prevented imitation. But in a weak appropriability regime, firms with superior complementary assets often profited most. Lieberman and Montgomery (1988) showed that being first on the market could carry first mover advantages beyond patent protection (learning curve advantages, the preemption of scarce assets, buyer uncertainty as to quality, and buyer switching costs). Such analyses are key to the arguments developed below on how firms can 'position' themselves to take advantage of R&D opportunities. Firms with superior complementary assets clearly also have private information relating to these assets.

How can firms exploit the information asymmetries arising from their R&D investments? Arguably, four basic strategies may be used.

4 Exploiting R&D Information Asymmetries: Four Strategies

4.1 Publication in Return for Legal Protection

With this strategy, the firm recognizes that information may well 'leak out' to rival firms, and decides to publish it, retaining proprietary control through legal means. Methods include patents, copyrights, design patents, and semiconductor chip protection (cf. Besen and Raskind, 1991). Depending on the method chosen, the type and degree of protection may vary.

A patent, for example, gives the inventor the legal right to exclude others from manufacturing and selling its new product or process for a given period of time (normally twenty years). In return, the inventor discloses the details of the new tech nology, so that others may learn from it and build on it. To be patentable, an invention must satisfy three criteria: novelty, non-obviousness, and industrial applicability. Patents are used in all industries, but are considered particularly important for inventions in pharmaceuticals, speciality chemicals, and for certain mechanically simple inventions which cannot be protected otherwise. A copyright, by contrast, gives the author the exclusive privilege of publishing and selling one particular work. It is mainly used in fields like book publishing, movies, popular music and computer software.

Intellectual property rights can also be used as the juridical basis for contractual agreements, such as patent licenses, cross-licenses, buyer-supplier contracts, and distribution agreements. A firm may decide, say, that it does not wish to manufacture its new product, but to earn royalties from it through licensing. Licenses can, if desired, be restricted to a single company, and/or particular geographical areas. Contracts based on intellectual property rights have the benefit that they clearly specify the legal obligations of the different parties, and what legal recourse is available in the event of contractual non-performance.

4.2 Keeping the Information Inside the Firm

Second, a firm might choose not to disclose information, but try to keep it inside the firm through secrecy, tacit and firm-specific knowledge. According to studies, secrecy is often used to protect process inventions, where would-be competitors can be barred from entering plant premises, and for inventions that resist reverse engineering. A classic case is Coca Cola, preserved as a trade secret for a hundred years until – quite recently – disclosed over the Internet. The disadvantage of secrecy is that if other firms discover the secret by legal means, they cannot be prevented from copying it.

An example of the competitive advantages that may be derived from tacit knowledge is the invention by Fläkt, a Swedish multinational, of a new drying system (the FC-dryer) for the pulp and paper industry (Zander and Zander, 1994). Very little information about the manufacturing activities was conveyed by blueprints, and manufacturing personnel had to undergo on-the-job training to learn their jobs. The manufacturing and materials technologies were too complex for any one or even a few employees to take to a competitor, and the technology was not imitated.

One cost firms may experience in using this second strategy is the high mobility of people, for when employees leave, they take their special skills and knowledge with them. Employment contracts often contain provisions prohibiting employees from using internally developed know-how in their new job. But such contracts may be difficult to enforce particularly when employees move abroad. Valued employees are also not easy to replace. Such costs are *ceteris paribus* not incurred for information publically disclosed in a patent or a copyright.

4.3 Make the Information Selectively Available on an Informal Basis

Informal knowledge exchange can be extremely valuable to innovating firms. Employees often need information in connection with their work that is very specialized and not published anywhere. They can either try to develop it themselves, or obtain it from an expert in another firm. In-house development can be very expensive, and it may make sense just to pick up the phone and ask someone.

A computer engineer reported, for example, that if he ran into a problem in developing a new software system, instead of trying (as in the past) to solve it himself, or consult a colleague, he would describe it on the

Internet. Within a day or so, someone usually contacted him with the answer, referring to a written source, or internal know-how. Later, he could return the favour. Often, the knowledge exchanged was proprietary. Characteristically, in this strategy, rents may accrue as a result of the controlled – and reciprocal – nature of information sharing.

Informal knowledge sharing can also be systematized, as Von Hippel and Schrader (1996) demonstrated in their study of the oil scout trading mechanism. All oil exploration firms face the problem that existing geological data and expertise is critical in the evaluation of a given area's potential for oil production. But some of this data is proprietary, held by rival oil exploration firms. To solve this problem, the industry has established groups of specialists called 'oil scouts'. These scouts are individually employed by their respective oil exploration firms. But if a scout's employer requires proprietary information possessed by a rival firm, she can arrange to meet her counterpart at that firm and propose a trade.

4.4 Rapid Dissemination by Making the Information Freely Available to All Comers

Finally, the firm may choose openly to diffuse the private information produced in its R&D laboratories, actively revealing it to other market participants, accelerating market penetration. Rapid dissemination may be implemented, say, by initially selling the new product at or below cost, or by adopting a liberal licensing policy granting the rights to one's new technology to virtually all comers. Thus Computer Associates gave away its Simply Money software on the expectation that favourable word-of-mouth would outweigh the expense of making the diskettes; further, the firm hoped that customers could later be persuaded to buy upgrades and related programmes. Nintendo distributed its game consoles to customers at or below cost, to boost sales of its software.[2] Such a strategy is particularly appropriate for industries characterized by network externalities, where the value of a good to each consumer increases, the more other consumers use the same or compatible products (cf. Katz & Shapiro, 1985).

The advantages of this dissemination strategy include not only the (short-term) benefits of seeing the technology become more widely known and used, but also the longer-term opportunity to earn rents by driving would-be rivals from the market once buyers have been 'locked in'. Some firms use this strategy to influence the formulation of international standards, which can later form an important future barrier to entry, as rivals must incur extra costs in adapting their production systems to the requirements of the standard. For technologies where buyer switching costs are high, the innovator can also gradually raise its price. The disadvantage is that once the information is released onto the market, the innovator may lose 'control' over what happens to it.

4.5 Combinations and Permutations

These four strategies can be combined in various ways. Thus patent licensing may be used in strategies (1) and (4). But the purpose and function is different. In strategy (1), the license serves mainly, together with the patent, as a barrier to entry. In strategy (4), it serves mainly to promote rapid dissemination. A firm might also seek to keep its process technology secret, but be indifferent as to how much information about its product technology leaked out to other firms.

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[2] And Rupert Murdoch, instead of denigrating the Indian upstarts who stole the signal from his News Corporation's Star TV satellite and resold the programmes to people over cable TV, reportedly characterized them as 'splendid entrepreneurs' who broadened Star's potential market and allowed Murdoch to raise his advertising rates (Gross *et al*., 1995).

5 Use of R&D-Generated Private Information to Earn Rents

A major advantage of analyzing R&D investments as a source of information asymmetries – as opposed to innovative capabilities – is that it considerably broadens the range of strategic acts available to managers, as will be explored below.

5.1 Use of Private Information in the Commercial Development of New Technologies

Firms can use the private information generated from their R&D investments to earn rents from the commercial development of new technologies by several means, including launching an independent research effort, building a research collaboration, coming second on the market, and strategic signalling. Critical to shaping firm choices in this regard is the nature of the information concerned. As Winter (1987) pointed out, some types of knowledge may have more of a 'public good' character than others (he distinguished between new knowledge that was largely articulable, observable in use, simple and independent, and that which was largely tacit, not observable in use, complex and an element of a system).

Product patents are considered an effective strategy of appropriability in the pharmaceutical industry, for example, because while the costs and risks of developing a new drug are extremely high, once the drug is on the market, it is normally relatively cheap and easy to produce. Thus the information cannot easily be kept secret. (Process technology, by contrast, is often kept secret in this industry). A further advantage is that it can be clearly specified what the molecular construction of new drug consists of, and how it fulfils the criteria of patentability, which can be harder to do for inventions in other industries (Levin *et al*., 1987).

In choosing this approach, the firm must decide, in effect, that the benefits of patent protection justify the release of valuable proprietary knowledge. The successful exploitation of this strategy is highly dependent on the efficacy of the legal system to function as it should. Firms operating internationally must secure intellectual property rights protection in every country in which they plan to market the good. The costs of implementation (including both application and enforcement) are substantial.

If the firm decides not to patent, it might attempt to protect the invention as a trade secret until the time comes to launch it commercially. Then, riding the waves of lead-time and learning curve, the firm can prevent imitation by maintaining its head start, based on technological superiority. The risks of implementing this strategy are, clearly, that competitors might introduce their own version of the product or service first – or that once the innovator's own goods are on the market, competitors will catch up. As Lieberman and Montgomery (1988) recognized, learning curve advantages often have little value unless they are kept proprietary.

Co-operative product development strategies enable the exchange of valuable information, both formally and informally. Advantages include sharing costs and risks, learning synergies, accelerated speed to market, low-cost entry into new industries and industry segments, and an enhanced ability to meet customer demands for integrated systems. Disadvantages include the possibility of misunderstandings, disputes and opportunistic behaviour. It may be difficult, for one thing, to find the right partner (due to the problem of adverse selection); the partner may not have the expected level of knowledge or skills; or the partner may abuse its access to proprietary knowledge. These points are well known and need not be further elaborated here, beyond the comment that the costs of co-operation will negatively affect the size of the potential associated rents.

Firms may also, through liberal patent licensing policies, expand the worldwide use of their innovation by rapidly disseminating it. Pilkington's development of a new process for making plate glass transformed the industry, enabling it to become the largest glass manufacturer in the world. Because the development costs had been so high, Pilkington licensed the process to its competitors. This strategy not only generated substantial royalty income, it also helped to make the new process the industry standard, and assured the continuation of Pilkington's technological leadership for decades.

An alternative approach is to come second on the market. A case in point, as described by Teece (1986), concerns the CT scanner, invented and originally marketed by the British firm EMI. But it was General Electric, thanks to its strong complementary assets (particularly its superior marketing and distribution networks) that eventually dominated this market. But (to use the logic of this paper), it was not just possessing these assets that helped GE to win. Drawing on the private information from its R&D labs, GE was able not only to evaluate EMI's capabilities, but also to develop its rival scanner. Combining this information with a superior understanding about how to succeed on the critical American market, it could draw off the lion's share of the profits.

Finally, through publicizing their investments in R&D, firms can 'signal' their intentions to competitors and users alike. In an example described by Kahaner (1996), during the 1970s and early 1980s, 3M dominated the worldwide videotape business. Japanese tape makers (Fuji, Sony, TDK, and Maxell) realized that consumers wanted longer-recording tapes. The 3M tapes could not meet this demand, because the plastic base film was too thick. No existing producer seemed interested in introducing next-generation technology for thinning the films. In 1980 the Japanese film producer Toray bought an expensive coating machine, signalling to the tape makers that it was initiating research to produce thinner tape. The tape makers joined the filmmakers to develop strong, long-duration tapes with a high quality image. Eventually, the Japanese firms marketed the longer-playing tape, apparently taking 3M by surprise.

Signals are an indication of strategic intent. They can forestall the actions of competitors or create uncertainty that may limit the ability to respond. By taking out a patent, for example, a firm lets other market players know that it considers that particular area important. This message can be sent regardless of whether or not the patented invention is developed commercially. Signals can affect customer expectations as well. Software companies sometimes announce the introduction of new systems that are years away from completion. According to the companies, announcements of this sort help users to plan. But competitors complain that preannouncements lead customers to wait for the new programme instead of buying their own products which may, in fact, be further along in the development process (D'Aveni, 1995, Kahaner, 1996).

5.2 Private Information and Related Market Opportunities

Private information from R&D can be exploited in several manners to earn rents in related markets: through mergers and co-operative agreements, speculation, using private information to derive the benefits of technology diffusion, and (again) signalling.

First, firms may use the information asymmetries generated by their R&D investments to evaluate potential take-over prospects. In the case of the CT scanner, as described above, GE used its private information not only directly, in the innovation process, but also to evaluate the skills and resources of the other scanner manufacturers on the market – some of which it eventually took over.

One of the more interesting results from analyses of the R&D consequences of merger activities is that acquiring firms, contrary to what might otherwise be thought, are either more sophisticated in terms of R&D, or

have R&D programmes equivalent to those of the target firms (Hall, 1987). There are few instances of firms 'substituting' a lack of internal R&D through merging with firms with heavy R&D commitments. One could claim that it takes sophisticated R&D programmes to develop the private information necessary to first identify potential target firms, and then after takeover to use the potential R&D synergies to obtain competitive advantages.

A prime example of the use of private information through takeover activity concerns the relationship between the established pharmaceutical FIRMs and new biotechnology enterprises (NBEs). The former, with their private information as to the costs of commercial development and marketing, allowed the one thousand or so NBEs to attempt to develop biotechnology products. The large pharmaceutical firms developed an expertise in biotech, but did not specialize in it, as did the NBEs. Thus while all large pharmaceuticals conducted biotechnology research, as of 1994 of the twenty-two biotech medical products approved for sale in the United States, only one was the product of a large pharmaceutical incumbent (Eli Lilly). Of the eight products under license, however, six were licensed to pharmaceutical incumbents. Of the twelve NBEs with the twenty-two approved products, five NBEs had been wholly or partially acquired by pharmaceutical incumbents. These five firms accounted for 13 (60 percent) of the 22 approved products (Zucker and Darby, 1996).

Alliances, mergers, and cooperative agreements permeate the biotechnology industry. Many of these forms of collaboration can be said to function as 'real options'. (Kogut, 1991, Burgers, Hill and Kim, 1993). By buying into several collaborations of this type, both NBEs and the pharmaceutical incumbents can create a portfolio of alliances, simultaneously diversifying their risks, increasing learning, and augmenting their sources of private information for future strategic use.

Private information may also be used for more speculative purposes. To return to Hirschleifer's (1971) story of Eli Whitney: the argument that Whitney could putatively have earned rents by investing in assets made more valuable by his cotton gin is intriguing. Yet such speculation also carries considerable risks, and the example can be criticized as unrealistic. Most firms have neither the time nor the resources to 'position' themselves to realize such benefits. There are several pitfalls here:

First, in many instances, the scope of effort to utilize private information for gain on related markets is too great. Such would probably have been the case with Eli Whitney. Yet too much can be made of this problem. For example, private information of one's own R&D effort could enable the innovator simply to purchase equities in the firms controlling these assets.

Second, other actors can react quickly to deprive a firm of the chance to earn rents. The degree to which private information remains private after the firm's first move into the market can be questionable. Put in the Eli Whitney context: could Whitney really have used his private information given the scope of his task and the fact that his related investment in, say, cotton plantations, might have been observable to others? Here, the context in which the private information is put has much to do with its success. There is considerable evidence that equity share prices often rapidly rise or fall after a market leader has 'moved' to take advantage of private information.

Then too, as Rosenberg (1995) has pointed out, it can be extremely difficult to anticipate the future applications of successful innovations, not least because most technologies come into the world in a very primitive condition. The first computer, the ENIAC, was huge and unreliable; this computer obviously had a limited market. But as the future would show, the demand for computers skyrocketed once they had been made smaller, cheaper, and more reliable. The point here is not that a firm should, necessarily, use its information to speculate, only that it should be aware of its option to do so.

Firms might, in other circumstances, find it in their interests actually to pay the manufacturers of complementary products to enter the market for their own goods. 3DO, for example, developed both the hardware and the software technology for a new generation of video games. To use the software, customers had to have the hardware. So 3DO gave away the licenses to produce the hardware technology, thereby inducing hardware manufacturers like Panasonic (Matsushita), Goldstar, Sanyo and Toshiba to enter this business. To create further momentum, it was best that these manufacturers sold the hardware below cost. Since they had no particular reason to do so on their own, 3DO additionally offered them 2 shares of 3DO stock for each machine sold (Brandenberger and Nalebuff, 1995).

A further example of the use of private information to exploit opportunities in related markets lies in the strategy of credible signalling. In industries characterized by multiple product firms, such signalling by an incumbent can be useful to thwart entrants. (Here, the incumbent threatens the prospective entrant by signalling that she could enter that firm's own main product markets, should the entrant insist on a debilitating foray into the incumbent's markets). Alternatively, a firm might signal the existence of private information as the basis for entering a joint venture with a firm further ahead in the field or with complementary expertise.

A firm might also build up its patent portfolio as a 'bargaining chip' in negotiating a cross-licensing agreement, giving it vitally important access to another firm's patented inventions in related areas. For if an innovator has little of value to trade, others will have no reason to deal (Grindley & Teece, 1997). 3DO's strategy of subsidising hardware manufacturers to produce hardware for its software can also, in this regard, be described as a form of signalling. The firm indicated to others that it planned to market this software widely, and that it was willing to lose money on the hardware portion of the business until its earnings could later be boosted by the sales of software.

6 Implications for Strategy

In making choices, the innovator must not only be flexible, adapting to changing technological and market conditions, but also take into account the counter-strategies available to competitors. Intellectual property rights, for example, have been described as a means of protecting private information. Yet because the information is published, rivals can read the patent document and use the revealed information to create their own, marginally different versions – or even infringe the patent.

That patents are systematically registered opens up a wealth of additional opportunities for firms seeking access to information. A statistical study of the patents granted in one's field of research can highlight which other firms and individuals are doing the leading work, in which countries. The individual patent document specifies whether the invention is the product of a joint research effort, whether it has been licensed out, and on which previous patents it is based. But patent-holders – for their part – are not without counter-strategies in this regard. Some, aware that competitors will scan the patent data for information about what they are doing, may seek to 'hide' their position: large multinationals can assign patent rights to a subsidiary; small firms can list the name of the owner as the assignee, not the company. In the case of joint ventures, the patent can be assigned to either partner.

Firms can keep rivals guessing as to their future plans. Intel has multiple capabilities, with strengths in microprocessors, other chips, flash memories, PCs and supercomputers. But it has not entered all of these markets. Not wishing to compete with its customers, for example, Intel has not begun to manufacture personal computers - even though it could. As a result, competitors can never be sure that Intel will not enter a given market in the future. Further, by maintaining a massive R&D presence, and signalling that it has plans for new

technological breakthroughs in chip technology throughout the 1990s, it encourages its customers to wait for its next chip rather than adopt those of its rivals (D'Aveni, 1995).

A related example concerns an announcement made by Glaxo, the leading pharmaceutical manufacturer in the areas of asthma relief products, that it was marketing a breakthrough product: a bronchodilator that also had an anti-inflammatory component. Glaxo's Swedish competitor, Astra, was concerned that this announcement would preempt its plans to come out with a similar product, which was not as far along. But when Astra's researchers studied Glaxo's clinical tests, they learned that the anti-inflammatory effect did not work on humans, but only on animals. Astra used this finding to calm industry excitement, and to give itself time for its own clinical trials and experiments. It received, in the bargain, data from Glaxo's clinical trials that they could use in their own research (Kahaner, 1996).

An innovating firm that lacks complete information about demand conditions can, by delaying product-specific investments, win time to obtain better information (McGahan, 1993). Waiting, however, may make it vulnerable to imitation. One solution is to introduce a prototype to test market demand. If demand proves lower than expected, the innovator can perhaps withdraw from the market; if demand proves higher, it can keep this information secret, and make the capital investment. In this way, first movers can deter would-be imitators without preemptive investment.[3] Alternatively, it can attempt to realize pecuniary gains from the investments in R&D by selling the information to another firm on the market.

A final method is to create buyer-switching costs. To counter this strategy, rivals can offer free samples or redesign their products to reduce customers' conversion costs. Thus computer software makers can include free samples on the hard disc drives of new computers, or package them with personal computers or peripherals.

7 MNE Organizational Advantages

Information asymmetry has been important to the analysis of the management of information flows in the multinational enterprise (cf. Hennart, 1991). Casson (1982), for example, argued that by integrating vertically, the MNE could reduce information asymmetry as regards the quality of its goods produced throughout the supply chain. Yet his focus is on market imperfections due to the problem of quality assurance, not R&D.[4] With regard to R&D, economic theories of the MNE have emphasized the importance of internalizing research results, due to imperfections in the market for knowledge (cf. Buckley & Casson, 1976). The problem of appropriability has been specifically used as an explanation for the growth of the MNE by Magee (1977). Again, these accounts do not discuss the information asymmetries arising from R&D.

Yet the MNE's organizational structure and 'deep pockets' can arguably provide a powerful advantage in exploiting the private information generated in its R&D programmes. In recent years, multinational

[3] For example, Phillips formed an alliance with Sony to establish a standard for CDs. But this sharing of key information also made Sony the best equipped competitor to follow Phillips onto the American market. Phillips decided not to make a large, product-specific investment in the American market, but initially to import CDs from Europe to test market acceptance. While the initial press reviews of the sound quality of the new CDs had been mixed, Phillips knew, from its private tests, that demand was strong. Keeping this information to itself, Phillips committed capital to building a U.S. facility for pressing compact discs. Once on the market, the CDs were extremely popular, and demand soared. As a result of this strategy, Phillips could use its first-mover position to dominate Sony and the other later entrants. On the other hand, had the initial tests shown that the market was not acceptable, Philips could quietly have withdrawn (McGahan, 1992).

[4] Suppliers, he argued, have an advantage over buyers (MNEs) in checking the quality of their products, since the information is created as a joint product of the supplier's production process. By integrating backwards into production, the MNE can gain access to this information directly.

enterprises have decentralized a rising portion of their R&D (OECD, 1998, Nobel and Birkinshaw, 1998). Overseas laboratories can play a number of roles (Eteman and Dulude, 1986, Pearce, 1997), from adapting products developed elsewhere in the MNE to local market needs to specializing in advanced scientific work. Such subsidiaries can contribute in various ways to the MNE's ability to use information. For example, subsidiaries can tap into foreign sources of knowledge through their access to the local technological infrastructure, including local suppliers, universities and other research institutions.

MNEs can also take advantage of their subsidiary network to establish scanning units worldwide to supply market intelligence and other information relevant to the product development effort, making a continuous flow of technical information available to the R&D centre, either via the Internet or in the form of meetings among the personnel of the different units. Many Japanese electronics firms, for example, have retained their development capabilities at home while dispersing numerous small scanning units (normally consisting of a few product designers) in their major foreign markets (Chiesa & Manzini, 1996). Other subsidiaries, called 'integrated laboratories', may provide basic or applied research inputs into a larger innovation programme, co-operating with laboratories in other countries and the parent laboratory.

An important issue concerns how the MNE can plan its international R&D efforts, and co-ordinate the resulting information flows, so as to maximize the rents that can accrue from working across countries - and so that the associated rents are not dissipated. The organization of multinational R&D projects involving several laboratories worldwide requires sophisticated co-ordination at all phases of the development process. Prior to the initial project definition phase, market intelligence flows from the different units to the central unit, which decides which projects to implement, and how the R&D is to be divided among the different units. During the development phase, information is continuously exchanged, helping the individual labs to develop their contribution to the overall project. Finally, the different subsidiaries can contribute in their own ways to the product's market introduction.

Similarly, the use of complementary assets to win over competitors by coming second on the market, as described earlier, requires formidable co-ordination skills, both in dealing with the MNE's different partners (suppliers, distributors, and so forth), and in grasping the relevant issues in many different countries. Clearly, appropriating rents from R&D carried out in foreign countries is a much larger and more complex endeavour than that confronted by Eli Whitney with his cotton gin.

8 Discussion and Conclusions

Private R&D information, it has been argued, can be used either in new product development, or in relation to other market opportunities. It can serve to facilitate an independent research effort, or it can be shared. It can inform investments in complementary technologies, to evaluate take-over prospects, to help the firm come second on the market, to signal strategic intent, or even to send false signals.

This focus on the potential rents arising from private R&D information is closely reflected in the desire, as expressed by many R&D managers, to use R&D more aggressively to enhance competitiveness.[5] Firms increasingly use gatekeepers and 'technology trackers' to keep abreast of the information advances occurring around them. ABB has developed a sophisticated process for assessing and improving its technological position – Business Technology Evaluation – to ensure that it makes the right investments in R&D (Stillman, 1997).

[5] According to the results of a 1995/96 Arthur D. Little survey of leading European Chief Technology Officers, R&D is being regarded more and more as a 'competitive weapon', intimately linked to business strategy (Sommerlatte, 1997).

This paper indicates one way in which MNEs might usefully envision the information emanating from their R&D activities as a source of competitive advantage.

Both the type of information, and the organizational capabilities of the firm concerned, are important in this regard. Clearly, some types of information can more easily be patented or kept secret than others, and some can be more easily exchanged (or disseminated). Organizational capabilities affect the firm's ability to implement the chosen strategy. While a small firm might lack the resources develop its invention commercially, it can license the rights to another firm, or to set itself up as a partner in a joint venture. A large multinational with many foreign subsidiaries might arguably be more effective than a small one in using its global marketing and distribution networks to disseminate its information as quickly as possible. But may be less able to recognize the value of the key information asymmetries generated in its decentralized labs.

Growing time pressures (shrinking product life cycles, the increased importance of speed to market) arguably raise both the tempo of innovation and, following the lines of argument in this paper, the incidence of the information asymmetries arising from investments in R&D. But they also shorten the 'life' of the asymmetries concerned, reducing the time that managers have at their disposal to decide what to do, and increasing the rate at which rivals will generate their own information asymmetries.

Each of the firm choices described in this paper involves its own set of costs and benefits. The costs of securing strong intellectual property rights protection, for example, may well exceed the benefits, if the product has a short life span. The costs of maintaining secrecy may be too great if the technology, by its nature, unexpectedly proves susceptible to reverse engineering. The costs of information gathering and verification as to the quality of the R&D programme of a potential take-over candidate might also prove prohibitively high.

Moreover, the fact that a firm has private R&D information may have a value in itself, above and beyond any specific strategic use. Investor knowledge that the firm has large reserves of potentially commercially valuable private information, for example, is often reflected in the pricing of traded shares. It may also make it easier to negotiate terms for receiving a bank loan, or for entry into a joint venture.

An important theoretical issue concerns the nature of the rents derived from the generation of private R&D information. The concept of 'information rents,' in the economics literature, has been mainly applied to the analysis of incentive contracts and principal-agent relationships (cf. Aoki, Gustafsson and Williamson, eds. (1990). In this paper, rents from investments in R&D are seen in somewhat different terms: as the returns in excess of the firm's opportunity costs accruing to it through its exploitation of private R&D information. In principal-agent theory, information rents are used in an *ex ante* contractual context.

That a high-tech firm has private information, unavailable to its competitors, which can be put to earning rents, is analogous to the agent in a principal-agent contract who can use its unobserved private information to earn rents. Yet in the logic of principal-agent theory, the contractual agent may only exceptionally reveal the private information on which its information rents are based. Doing so can lead to renegotiation of the contract, and an elimination of information rents, if not loss of the contract. In the perspective outlined here, the firm may seek to increase its 'information rents' by either keeping the information private or revealing it (or some combination), depending on the circumstances. This concept could profitably be the subject of future research.

The approach outlined here could arguably also help managers to design an implement an active 'information policy'. When R&D investments are seen primarily as generators of private information – rather than new products and processes alone – a new perspective on managing R&D to enhance competitiveness opens up. Conceivably, a firm could invest in R&D but engage in very little innovation as such – and yet still

turn a profit because of its successful use of information. Even if a given innovation fails, the information that went into producing it can be reapplied in other contexts.

Investment in R&D, in this view, is also an investment in enhancing the ability of R&D personnel to think strategically about their work, and to find ways to use the information asymmetries thereby created to help their firm to win competitive advantage. Many of the ways in which this can be achieved – such as investments in complementary technologies and strategic signalling – are not the traditional province of the R&D department. But strategic decision-makers are unlikely to be aware of the full potential of the private information generated from investments in R&D. To the extent that firms fail to link opportunities from R&D-generated information asymmetries and management decision-making together, they may miss key rent-generating opportunities.

Not all of this private information will have commercial value. Some means needs to be developed to distinguish between the relative importance of the different types of information generated from R&D. Also vital is the ability to evaluate the research results of other companies. All of these efforts need to be co-ordinated. The challenge is to design strategies (and counter-strategies) to enable managers to position their firms not just at the forefront of the technological edge - but also, more fundamentally, at the *information* edge.

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