Industrial and Corporate Change, Volume 13, Number 3, pp. 451–475
DOI: 10.1093/icc/dth018

Specialized supply firms, property rights and firm boundaries

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The proper specification of intellectual property rights (IPRs) is a delicate and controversial matter. In this paper, we consider one specialized context in which IPRs can add to efficiency. We build on contributions of both 'firm capabilities' scholars (e.g. Teece, Pisano *et al.*) and 'property rights' economists (e.g. Hart) to show that IPRs can affect efficiency by influencing the location of technological innovation. Using a simple set up, where the key choice is whether a technology-intensive input will be supplied by an independent firm or produced in-house, we analyze how the choice is affected by the strength of IPRs and by the existence (and nature) of information spillovers. Specifically, we show that when the supply relationship is likely to produce new information of value to the supplier, stronger property rights favor independent suppliers over vertical integration. An important implication of our model (backed by empirical case studies) is that strong IPRs therefore encourage investments in specialized firms with strong 'firm capabilities' in the area of innovative input supply. IPRs therefore may play a role—along with multiple other factors—in the location of firm boundaries in some cases. This contribution to the viability of small, specialized firms, with their superior ability to innovate in some cases, must be taken into account in evaluating recent criticisms of over-fragmented IPR ownership (i.e. the 'anticommons' problem). It also contributes to an understanding of IPRs in the 'post-Chandlerian' economy, where smaller, specialized firms play a prominent role.

1. Introduction

The proper specification of intellectual property rights (IPRs) is a delicate and controversial matter (US Federal Trade Commission, 2003). There is little doubt that in some respects IPRs have been expanded and strengthened in ways that are difficult to justify. Patents on methods of doing business (Merges, 1999) and the lengthening of copyright protection beyond its already generous term (Merges and Reynolds, 2000) are two recent examples. In this paper, however, we consider one specialized context in which IPRs can add to efficiency. The traditional economic justification for IPRs states that without these property rights there will be an undersupply of new technology, and that therefore legal incentives to innovate are necessary. This very general story takes no account of the different innovative capabilities of large, integrated firms and small, specialized firms. In this paper, we add a transactional dimension to the discussion. We show that in one limited context, stronger IPRs make it possible for technology-intensive inputs to be supplied by separate firms. This, in turn, contributes to the viability of these specialized firms as standalone entities. Because smaller, more dynamic firms are in some cases especially innovative, IPRs are shown to contribute to innovation in a more nuanced, indirect way than under the traditional view.

More fragmented ownership may lead to higher transaction costs in some cases, as described in the literature on the 'anticommons' problem (Heller and Eisenberg, 1998). Nevertheless, recent scholarship suggests that the 'anticommons' problem may not be as ubiquitous as some have feared (Cohen *et al.*, 2003). In any event, proper evaluation of the anticommons problem, and IPR policy generally, is possible only when the benefits of specialization and new firm entry are considered. Hence the benefits of IPRs in contributing to small-firm viability—the primary topic we discuss—are highly relevant.

In discussing the 'transactional' role of IPRs, we build on contributions of both 'firm capabilities' scholars (Teece, 1988; Teece *et al.*, 1997) and 'property rights' economists (e.g. Hart, 1995). To appreciate how our analysis draws from each, consider a simple scenario. Suppose a manufacturer, henceforth the Buyer (B), requires a specialized input. Assume further that this input is the unique specialty of scientists and engineers who comprise a research unit, henceforth called the Supplier (S). One way for B to get the input is to employ 'Group S'—vertical integration. In the alternative, members of S could found an independent firm (Firm S) to supply the input to B through an arm's-length contract.

We begin from the 'preference of many engineers and scientists to work in smaller and more intimate organizations' (Freeman and Soete, 1997: 239). This preference may translate into efficiency gains: the members of Group S, constituted as separate Firm S, may perform better if they can form a separate firm. In a separate firm, the *esprit de corps* of the S group will not be diluted by the presence of an overarching corporate structure, with its inevitable costs in the form of bureaucratic hassles. Thus, all other things being equal, Group S may prefer independence.

What about Firm B? Although the S group might prefer independence, integration does have some significant benefits. In thinking about the costs and risks of dealing with an independent supply firm such as S, firm B may consider carefully the nature of the input to be supplied. Where the input must be adapted to Firm B's production process, much information will be exchanged by the two firms.Integration has a distinct advantage for Firm B: greater control over disclosure of internal information is a well-recognized feature of the employment relationship, as compared with independent contractor status (Masten, 1996). More generally, it seems reasonable that compared with an integrated entity, two independent firms will be less effective in coordinating the exploitation of information spillovers. As a result, it is likely the combined entity will earn a higher profit from the information spillovers than the sum of the profits of the two independent entities. Put differently, integration avoids rent dissipation from information spillovers.

On the other hand, completely apart from the preferences of Group S, Firm B understands that if Group S goes to work for Firm B—if S and B integrate—then Firm B sacrifices the high-powered incentives possible in arm's-length contracting (Coase, 1937; Teece, 1988; Williamson, 1996). Firm B may lose something important when S must expend considerable effort in adapting the input to B's needs (Baker *et al.*, 1997). A contract may better motivate Group S to effectively employ its special knowledge and talent in adapting the input to the needs of Firm B.

But, as both Firm B and Group S know, there are limits to contracts. It may be difficult or impossible *ex ante* to know what price Group S should charge for the final, closely adapted input. It may also be impossible to write an enforceable contract describing the level of effort Group S is to employ in adapting its input to Firm B's needs. In the absence of an effective contract, Group S would need some other safeguard to protect its expenditures on adaptive effort. In other words, the viability of constituting Group S as Firm S may well depend on the ability of S to prevent expropriation by B using some mechanism other than a straight contract. There are multiple ways to mitigate the expropriation risk, including development of complementary or 'co-specific' assets (Teece, 1986), the evolution of trust over time (Teece, 1989: 41), and through property rights, as set out in both the 'dynamic capabilities' literature (e.g. Teece, 1989: 39–40) and the literature on property rights and firm boundaries (e.g. Grossman and Hart, 1986; Hart and Moore, 1990; Hart, 1995).

In this paper we capture a stylized version of this tradeoff by modeling the 'make-buy' decision as a tradeoff between incentives and rent dissipation. The model assumes the existence of special capabilities in the hands of Group S, which Group may either become a division of Firm B or a separate Firm S. From Firm B's perspective, as Pisano *et al.* (1988) have pointed out, the decision to outsource knowledge or technology intensive activities—i.e. to contract with Firm S—depends in part on whether the required capabilities already exist in-house. In its simple version, our model represents a special case of this dynamic—the case where an independent group of specialists, Group S, possesses something Firm B wants—either capabilities, or the potential to develop them. From this perspective, we model situations where Firm B and Group S must jointly determine the best location for Group S's distinctive capabilities: either inside Firm B or outside it, in independent Firm S. In later sections of the paper, we adapt the model to the situation where Firm B is considering spinning off a current division (Group S) as a separate firm (Firm S). Thus our model can be seen as a formalization and expansion of the dynamic features of the firm capabilities literature, leading to insights concerning the location and extent of specialized capabilities.

In addition, considering the period just prior to the point when our model begins reveals an important feature of the capabilities story in the buyer-supplier context. Under some circumstances, *Firm* S has a potential performance advantage over *Group*

S, a division of Firm B. This advantage may well translate into higher investments in the building of Firm S capabilities. Therefore, the viability of Group S as separate Firm S can, under some circumstances, lead to higher investments in specialized capabilities such as those required to adapt an input. When strong property rights play a role in this enhanced viability, they contribute indirectly to the creation of superior capabilities. Thus the traditional rationale for strengthened IPRs is given a new twist: property rights contribute to the locus, and not simply the extent, of investment. And in this way, IPRs are seen to play a part in the trend toward 'dis-integration' and the emergence of 'post-Chandlerian' industry structures.[1]

Pisano *et al.* (1988) and von Hippel (1994, 1988) point out that outsourcing may entail additional information exchange and coordination costs, due to tacitness of knowledge and inter-dependencies in activities undertaken inside and outside the firm. This paper sheds light on these issues as well. Formal legal property rights (particularly patents) involve the 'codification' of information, which might in some cases contribute to 'unsticking' that information (in von Hippel's sense) and thereby making it easier to transfer. Some studies show, for example, that 'formal' IPRs can increase the rate of transfer of unprotected information (trade secrets and know-how) (Arora, 1995). Where the performance of a research group such as Group S would be better outside Firm B, but the special capabilities of Group S are 'sticky' with respect to complementary assets held by Firm B, the availability of property rights may encourage Group S to invest in 'unsticking' its know-how from the Firm B context. In this way, stronger IPRs may play a role in resetting firm boundaries.

The remainder of this paper proceeds as follows. In Section 2, we motivate our formal analysis with a case study of an agreement between a pharmaceutical firm and a specialized input supplier. This example shows that the contract is highly incomplete in two important respects, which we model in Section 3. The first source of incompleteness is that the supplier has to make substantial non-contractible relationship-specific investments. Our model shows how S's intellectual property rights mitigate this incompleteness. The second source of contract incompleteness is due to information spillovers, which arise from the extensive interactions and information exchanges between S and B. Spurred by evidence from this and other real-world contracts, we model two types of information spillovers: (i) leakage of B's pre-existing information; and (ii) synergistic generation of new information. Another feature of real-world agreements leads to another aspect of this paper: the importance of intellectual property rights (IPRs). We study how the strength of IPRs affects the 'make-buy' decision under different types of information spillovers. We extend our model in Section 4 to allow for buyouts. In the concluding section we summarize our

[1]It is a bit of shorthand to refer to large, vertically integrated firms as 'Chandlerian' firms; it is quite clear that the influential historical studies of Alfred Chandler can be read as entirely consistent with the recent emergence of far more variegated, less vertically integrated structures. For an excellent survey of these issues, see Langlois (2003).

main findings and their testable empirical implications, and marshal empirical evidence from the literature that supports the main underpinnings of our model.

The emphasis on information in this paper draws from three sources: (i) transaction cost economics; (ii) the 'firm capabilities' perspective associated with Teece (e.g. Teece, 1988); and (iii) the property rights-firm boundaries approach (Grossman and Hart, 1986; Hart and Moore, 1990; Hart, 1995—henceforth GHM). From the transaction costs and firm capabilities perspectives we take it as given that innovation depends in part on often-tacit firm-level know-how and the presence of important complementary assets, i.e. firm capabilities. Implicit in our approach is the view that in some cases, specialized suppliers have the potential to generate useful know-how and build firm-level capabilities that will be superior to those that can be generated in a large, integrated firm. Appropiability, in our story, thus creates incentives for the creation of know-how and complementary assets. In this sense, our analysis moves the Teece approach back one period—demonstrating in one important context (the specialized, small-firm supplier) where superior firm capabilities come from.[2] Enhanced appropriability, in other words, makes it possible for a specialized supplier to 'go it alone,' thus facilitating independent firms in settings where those firms have the potential to build the capabilities that make them superior innovators.

We borrow from GHM the idea that allocation of property rights over productive assets can be used to structure incentives and thereby affect firm boundary decisions. In our model, the allocation of intellectual property rights (IPRs) plays an analogous role, although we extend the usual analysis by adding a new variable: the strength of property rights. We examine how varying the strength of IPRs influences firm boundary decisions. We also assume a more dynamic contracting environment. GHM models have two stages: parties make investments in stage 1, and transfer assets in stage 2. Our model also incorporates an open-ended stage 3: the period after the sale of the input, when the parties may make use of information revealed during the transaction.

IPRs provide important incentives to the creation of new technologies. But their role in the 'make or buy' decision—and in structuring transactions generally—has received little direct attention. Exceptions include earlier work by Teece pointing out the importance of 'appropriability' considerations to innovation and vertical integration decisions in particular (Teece, 1986), and some recent work linking stronger IPRs to increased transactional volume (Anand and Khanna, 2000) and the choice of contract over hierarchy in governing transactions (Oxley, 1999). Research on the emergence of specialized, IPR-intensive supplier firms, described, for example, in Ham-Ziedonis and Hall (2001) for the semiconductor industry, also emphasizes the importance of property rights for firm strategy. Similar trends in biotechnology and specialty chemicals are described in Section 5 of this paper.

A recent paper, by Kim and Marschke (2001) argues that firms patent to protect

[2]It can be read therefore as an attempt to bridge the gap, noted by Dosi (1997: 1533), between 'firm-specific capabilities' and 'fine variations in profitability incentives'.

themselves from their R&D workers, who can quit to join or to start rival firms. Patents reduce the payoff an R&D worker can hope to get by quitting. In our model, the independent supplier's patents reduce the payoff to the buyer from trying to holdup the supplier after the supplier has sunk its customization effort. Further, in our model, an independent supplier can use information that it acquires from the buyer during the contract period, in ways that reduce the payoff to the buyer. Kim and Marschke (2001) ignore the problem of providing the R&D employee with the incentives to make non-contractible investments in research, a key issue in our paper. However, our paper neglects the possibility that a captive supplier could quit the parent firm and join a rival. This neglect explains why we focus only on the impact of patents held by the supplier.

2. Case study: the Alkermes–Genentech supply agreement

To give a real-world context for the situation we are modeling, we describe a representative collaboration in an IPR-intensive industry: a joint development agreement between Genentech, the largest biotechnology company in the world, and a very small firm specializing in sophisticated drug delivery technology, Alkermes, Inc.

Alkermes has developed a procedure for coating active drug ingredients in very thin polymeric capsules. The capsules are made of material that breaks down over time in the human body. Unlike traditional encapsulation, Alkermes's technology yields much smaller microcapsules and can be used on ingredients that have traditionally fared poorly in encapsulated form.

It is important to recognize at the outset that there is no hard and fast reason why Genentech could not pursue advanced delivery systems itself. Genentech has mastered very complex manufacturing problems relating to a number of its biotechnology products. Likewise, the high R&D intensity of the drug delivery business is no barrier; Genentech pursues R&D of unmatched depth and breadth in the biotechnology industry. And there is no legal or regulatory barrier keeping Genentech from this line of business. Clearly, consistent with the dynamic capabilities framework (Teece, 1988; Teece *et al.*, 1997), there is something about the capabilities of Alkermes that makes it attractive for Genentech to buy from Alkermes. And Genentech is not alone. Alkermes has deals with other firms such as Schering-Plough and Johnson and Johnson. As noted in the introduction, our interpretation is that Alkermes has developed and deployed these capabilities as a separate firm partly through the protection offered by strong patents.

The basic structure of the Genentech–Alkermes deal involves two stages.[3] In stage 1, Alkermes adapts its microencapsulation drug delivery technology to Genentech's successful therapeutic product, a genetically engineered form of the naturally occurring

[3]License Agreement Between Alkermes Controlled Therapeutics, Inc. and Genentech, Inc., effective November 13, 1996, attached as Exhibit 10.3 to SEC Form 8-K, filed by Alkermes, Inc., on November 14, 1996, available on SEC EDGAR database at www.sec.gov/edaux/formlynx.htm (hereafter 'Genentech–Alkermes Agreement').

protein called human growth hormone (HGH). In stage 2, Alkermes manufactures the product for Genentech and sells it at a pre-agreed price, with Genentech then marketing and distributing it.[4] Interestingly, Alkermes is required to make substantial investments in adapting its technology to Genentech's product and in creating the production process needed to manufacture it.[5]

Clearly, given its commitment to purchase from Alkermes at a pre-determined price, Genentech faces the risk that Alkermes will provide a low quality or an inadequately adapted product. The agreement protects Genentech by giving it a very broad right of unilateral termination: basically, at any time for any reason, prior to Alkermes's commencement of commercial manufacture, and upon six months notice after commercial production. And Genentech has broad power to decide whether Alkermes is living up to its obligation to produce to Genentech's standards.

Genentech's broad powers imply a great deal of risk for Alkermes. It could easily invest millions of dollars in the R&D and scale-up needed to meet Genentech's predicted demand, and then see the entire deal terminated with little recourse. The License is quite explicit in this respect (§ 4.3(A)):

> Alkermes shall be responsible for, and shall use its commercially reasonable efforts to, scale up the process for producing Licensed Product for both clinical and (unless Genentech manufactures commercial Licensed Product pursuant to Section 5) commercial requirements provided that Genentech supplies sufficient quantities of human growth hormone (at Genentech's expense) to enable Alkermes to do so. Exhibit C attached hereto sets forth the anticipated timeline, requirements and costs for scaling-up the manufacturing process for making Licensed Product for clinical and commercial use to treat [P]ediatric [Growth Hormone Deficiency]. *Genentech shall not be responsible for any of Alkermes' capital cost of its facilities* except as otherwise set forth in Exhibit C or approved by the [joint development committee set up by the companies under the agreement].[6]

[4]Alkermes-Genentech Agreement, § 6 ('Genentech agrees to pursue a diligent sales and marketing effort for a Licensed Product to be sold by Genentech relative to other products of similar commercial potential that are being sold and marketed by Genentech.') There is a pre-agreed price for the sale of microencapsulated HGH in the Agreement (License Agreement § 5.1), and Genentech's broad termination right gives it in effect the power not to exercise the option (§ 9).

[5]This is evident from the License Agreement, which contemplates the creation of 'Alkermes Knowhow,' defined in § 2.1 as 'data, . . . knowledge, discoveries, . . . specifications, . . . methods, processes, and techniques' during the course of the Agreement. As expected, Alkermes grants a license to Genentech for the use of this know-how during the course of the agreement, but such information is rarely set down in 'codified' form and hence is difficult to monitor or transfer.

[6]The Agreement on file with the SEC had these provisions redacted. It is very unlikely that these exceptions to the 'no capital contribution' clause were significant, however, for two reasons. First, a large dollar value item would be unlikely to be relegated to an Appendix of the Agreement; it would

So what protection does Alkermes have? One important protection is ownership of the assets required for the production of the microencapsulated drug that Genentech wants. While some of these assets do take on a tangible form, it is clear that Genentech could duplicate the production process if it wanted. (Indeed, it has the right to take over production if it deems Alkermes's efforts unsatisfactory, and it has world-class production facilities at its disposal with which to do so.) What is left, in a word, is patents. Consistent with the predictions of earlier work (Teece, 1986) and the theory developed here, Alkermes is 'patent intensive'. Alkermes currently has 43 patents, covering (i) its microencapsulation process; (ii) novel polymers and preparations that make up the coatings; and (iii) microencapsulated formulations of the drugs it delivers under its collaboration agreements.[7] These patents provide a fallback in the event that Genentech does not continue with the agreement. The patents prevent Genentech from using the Alkermes technology after the Agreement is terminated. In our view, these patents contribute to the viability of Alkermes as an independent firm—they form a key incentive for Alkermes to invest in the sorts of know-how and other assets that are complementary to those of its customers, such as Genentech. This is precisely what we mean in Section 1 of this paper when we speak of patents providing an incentive not just for creation of new technology, but for enabling that technology to be developed and transferred by independent firms such as Alkermes.

To summarize: the Genentech–Alkermes agreement is structured to protect Genentech against inadequate effort by Alkermes to customize Alkermes microencapsulation technology by giving Genentech broad rights to compensate Alkermes only when Genentech is satisfied with Alkermes's efforts. The agreement relies upon Alkermes's microencapsulation patents to protect Alkermes against an opportunistic exercise of Genentech's broad rights. Evidence from other Alkermes supply agreements supports the thesis that Alkermes always 'takes back' its technology when collaboration is terminated, e.g. because of unsatisfactory progress.[8] Alkermes's patents over the

likely have been heavily negotiated and hence incorporated into the body of the contract. Second, a large contribution by Genentech would have had to be recognized somewhere on Alkermes's books, and reported as 'material' under the Securities laws. No such item appears in the associated financial statements, however. See also Agreement Between Alkermes and Pharmaceutical Research, Inc., Exhibit 10.25 to Alkermes's SEC Form 10K, filed June 29, 1998 (available at http://www.sec.gov/Archives/edgar/data/874663/0000950135-98-004071.txt), at § 2.6: 'The purchase of any capital item reasonably required by [Alkermes] to conduct Research shall be [Alkermes'] obligation and responsibility and all costs associated therewith are to the account of [Alkermes].'

[7]As of 2000, Alkermes had 43 US patents, numerous foreign counterparts, and more on file. See Alkermes, Inc., SEC Form 10-K, filed March 31, 1998, available at www.sec.gov/edaux/formlynx.htm at p. 19 ('Patents and Proprietary Rights'); updated 12/8/00 with search of www.uspto.gov.

[8]See, for example, the press release, April 22, 2000, 'Update on collaborations: undisclosed compound,' available at www.alkermes.com/news (emphasis added): 'Alkermes today announced the mutual termination of a collaboration with [a division of Johnson and Johnson] for the development of a sustained release formulation of a . . . product candidate for the treatment of hormone-mediated disorders. The identity of the product candidate has never been disclosed by the parties. With the

design and implementation of its input technology thus play an important role in limiting Genentech's ability to act opportunistically.

Alkermes has now adapted its microencapsulation technology to a number of highly profitable pharmaceutical products sold by other firms. It has also obtained four patents on the microencapsulated form of Genentech's HGH, applied for after the commencement of the Genentech relationship. Clearly, Alkermes is deriving significant synergies from its interactions with buyers such as Genentech, and that Genentech may also have benefited from this relationship.[9]

Information spillovers from such deals do not always benefit both parties, as evidence from some recent cases shows. For instance, *Simula, Inc. v. Autoliv, Inc.*[10] involved a small firm (Simula) that had designed an innovative air bag component. Simula entered into a supply contract with a large manufacturing company in the auto industry, Autoliv, a preferred supplier to major auto companies. Simula disclosed its proprietary technology to Autoliv in connection with a deal to supply BMW with head restraint airbags. Autoliv then approached Mercedes, which asked Autoliv to design and supply a modified version of the Simula design as a head restraint system in Mercedes cars. Autoliv did so, submitting a modified design based on the Simula technology, but without including Simula in the deal. Simula perceived that its technology was being used in the Autoliv–Mercedes design, and brought suit to prevent being 'squeezed out.' Extensive litigation followed, with Simula fighting in multiple legal forums to stay an active player in the market for its specialty air bags.[11]

Our working paper (Arora and Merges, 2001) provides other examples where proprietary information leaked out from one partner and was used by the other in ways that significantly reduced profits for the owner of the information. And it is clear from conversations with managers and from the literature that managers are very concerned about proprietary information leaking out to partners in outsourcing arrangements and being used in ways that hurt the firm.[12]

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termination of the collaboration, Alkermes regains rights licensed to IPR for the development and marketing of sustained release formulations of this class of compounds.' Note (i) the recapture of rights and (ii) the fact that Alkermes acquired additional expertise, given that its part of the project was accomplished successfully.

[9]Internal evidence from the patents themselves supports this view. Alkermes's US Patent to Johnson *et al.*, US Patent 6,051,259, 'Composition for Sustained Release of Human Growth Hormone,' issued April 18, 2000 (assigned to Alkermes, Inc.), contains a detailed example in the specification that cites and relies on Genentech's proprietary HGH cloning and expression technology.

[10]175 F.3d 716 (9th Cir. 1999).

[11]Telephone interview with John Alan Doran, attorney for Simula, Inc., 12/4/00.

[12]While it is difficult to quantify 'typical' rates of information exchange in buyer-supplier contracting, legal disputes and practitioner guidance relating to these transactions provide some insight (Valz, 2004). Theft of trade secret cases arising from this context are common. In addition, lawyers often advise clients to contemplate the degree of information exchange that may accompany a supply contract, and to take precautions to prevent undesired leakage (Pooley, 1999: 634). R&D Managers are

In the next section, we develop a formal model that captures the main elements of the story. We show how patents can be used to structure contracts that provide incentives for customizing the input for the buyer. We introduce non-contractible information spillovers in the model and study the choice of organizational form and how intellectual property rights affect this choice. Again, our emphasis is on the transactional role of patents—how property rights enable the supply of highly specialized, customized inputs to come from independent firms.

3. The Model

Let $V(x)$ be the benefit to the buyer, B, from the purchase of the specialized input, where x represents the stage 1 effort by the seller, S, to customize the input. We assume that $x \varepsilon [0, X]$, where the baseline level of effort, which can be verified, is normalized to 0, and X is the maximum level of effort. The cost of customization is $C(x)$.

We assume that $V(x)$ and $C(x)$ are increasing and concave in x. Customization usually requires information flows between B and S. Information flows, though helpful for customizing the input, can reveal valuable information about B to S and vice versa. If both B and S are part of the same firm, revelation of proprietary information is of no consequence. However, if they are independent firms, B may be able to use the information in ways that reduce S's rents. For instance, it may reveal this information to S's rivals. In principal, the situation is symmetric but for simplicity we focus only on the possible leakage from S.[13]

Information exchange can also lead to the synergistic creation of new information. New applications and extensions of the technology may be revealed. Regardless of whether the information flows result in the creation of valuable new information or merely a leakage of proprietary information, or some combination thereof, insofar as S and B are independent firms their uses of this information may be competitive. This

well aware of this problem. For instance, Ragatz *et al.* (1997: 199) point out that fear of information sharing in new product development outsourcing agreements is common. Stump and Heide (1996) describe techniques for 'controlling supplier opportunism'. For a good overview, see Handfield *et al.* (2000). The management literature shows an awareness of these opportunities for synergy, as the following statement cited in Stuart and McCutcheon (2000: 35) notes: 'They [suppliers] are in on the engineering meetings. They can drop in on the research guys. They know more about our requirements than some of our own people do and are instrumental for concurrent engineering of new products.' McCutcheon *et al.* (1997: 275) conclude, based on an empirical study of 79 cases of outsourcing involving new component or product design, 'Increasing the role of the supplier in design enables the buyer to tap more effectively into the ideas of the supplier for product improvements'. Sen and Rubinstein (1989: 130) find, in a study of 31 technology outsourcing contracts, a 'high level of R&D involvement by the buyer firm', which includes 'new uses, new applications, and new products'.

[13]To the extent that only S becomes aware of the new application, this is formally equivalent to a reduction in cost, $C(x)$, and likewise, if only B becomes aware of the new application, this is equivalent to an increase in $V(x)$.

will lead to lower combined profits compared with the situation when S and B are part of the same firm. In other words, integration prevents rent dissipation.

In principle, even independent firms might try to negotiate to avoid rent dissipation. However, certain types of contracts, such as non-compete agreements between potential or actual rivals, are *per se* illegal. Likewise, nondisclosure agreements between independent parties are difficult to enforce, owing in part to the complexity of defining the information to be kept secret and separating it from the pre-existing information of the parties. Some of the same issues plague nondisclosure agreements between employers and employees. Certainly employees sometimes quit to join or start rival firms, thereby effectively dissipating some rents. But once again, an employer has more effective protection than a mere buyer. Safeguarding employer information is one of the primary goals of trade secret law (Merges *et al.*, 2003). One important manifestation of this policy is that the law usually implies an obligation of confidentiality for employees. In contrast, confidentiality must be spelled out in detail to establish such a duty between independently contracting parties. Detailed negotiation and drafting of this sort is of course costly (Zeckhauser, 1996). For this reason alone, in general rent dissipation will be lower under integration than with an independent supplier. For simplicity, therefore, we ignore the possibility of employees leaving to join rivals, as well as the possibility of the S and B negotiating to avoid rent dissipation in stage 3.

We model this as follows. After the customization is completed, with probability $p(x)$, S receives a payoff of Π^S, and with probability $1 - p(x)$, it receives a payoff of zero.[14] The integrated entity receives a payoff of Π with probability $p\ (x)$ and zero with probability $1 - p(x)$. We assume that $p(x)$ is increasing in x so that greater effort by S increases the probability of information spillover.

We assume throughout that $\Pi \geq 0$ so that information exchange is never harmful in a combined entity. We assume throughout that although both parties anticipate possible information spillovers, they cannot write contracts contingent on the spillovers. Were such contingent contracts possible, risk neutral agents would simply fold back-expected stage 3 payoffs into stage 2. We define *leakage* as the case where $\Pi^S = \Pi_L{}^S < 0$. *Synergy* is defined to be the case where $\Pi^S = \Pi_\sigma{}^S > 0$. Whereas synergies correspond to additional value created from the interaction, no such additional value is created under leakage. *Rent dissipation* implies $\Pi > \Pi^S$, so that the integrated entity always earns a higher payoff from information exchange than the sum of the payoffs of the two independent entities. Note that rent dissipation takes place under both types of spillovers.

The timing and structure of the game is as follows: S begins the game with a property right (i.e. patent) over the general design of its input. At this stage, the two firms decide whether to integrate or not. If S and B are part of the same firm, the property rights belong to the firm as a whole. If they remain independent, they negotiate a first period

[14] Since B's actions do not affect information spillovers, allowing for it to also get a payoff Π^B would not affect any of our results. If B could also take actions to affect spillovers (as we analyze in our working paper) then a richer set of possibilities emerge.

payment from B to S. The role of this first stage payment, T_1, is essentially to divide the total surplus between the two. After this, S chooses x. We assume that x is not contractible, but both B and S can observe the levels of x. This concludes stage 1.

In stage 2, S and B negotiate second stage payments, T_2. At this point, x is 'sunk', thus opening the door to potential holdup problems. The threat points of the two parties determine the outcome. If S and B are independent, B can threaten to end the relationship. Should B do so, S will withdraw its input. After termination, B would be able to duplicate S's design of the input, or transfer the S design to a third party supplier, getting a net benefit of $kV(x)$, where k is between 0 and 1. This formulation is similar to the one used in Gallini and Winter (1985) and Arora (1995; 1996). A decrease in k corresponds to an increase in the 'strength' of patent protection. Note that we assume that the ability of B to produce the input for itself may benefit from the effort S makes in customizing the input.[15] Under integration, S does not have the right to withdraw the input, and hence, B is not obliged to make any payments to S.

In stage 3, which is unique to our model, the information flows result in information exchanges with probability $p(x)$. Stage 3 may be thought of as the post-contractual period: the 'out years' when learning gained during the supply relationship is applied to the economic activities of S and B. We assume that an independent S and B cannot effectively contract not to compete with each other in stage 3, implying rent dissipation in stage 3.

We use the Nash bargaining solution and assume that the parties split the surplus. Given the structure of the model, this implies that S and B will be independent firms if and only if independence yields the higher surplus.

3.1 Patents and the incentive for customization without information spillovers

To highlight the problem of incentives for customization and the role of patents, we first analyze the special case where there are no information spillovers and stage 3 is absent. We demonstrate that patents can make possible contracts where an independent Firm S invests in customization.

Integration. Under vertical integration, B (more precisely, the combined entity) owns the inputs and any associated intellectual property rights and S cannot withdraw its inputs in the event of a disagreement. Accordingly, S has no incentive to invest effort beyond the baseline level $x = 0$.

Independent S. Assuming that both firms split the stage 2 surplus, we get

[15] B learns from S in several ways: directly, through sharing of blueprints and the like; indirectly, e.g. by closely inspecting the physical embodiment of the input; or through some combination of the two. In this sense it is not particularly important what form the input takes. If S is a software supplier, for example, it could supply B either with finished computer code to be directly incorporated into B's own end-user software product, or with 'high level' design information on how to achieve a particular software objective. We assume only that the input supplied by S has a high degree of information content.

$$T_2 = \arg\max(V(x)) - T_2 - kV(x))^{1/2}(T_2)^{1/2} \tag{1a}$$

$$\Rightarrow T_2 = ½(V(x) - kV(x)) \tag{1b}$$

In stage 1, S chooses x

$$x = \arg\max\{½(V(x) - kV(x)) - C(x)\} \tag{2}$$

Equation (2) shows how patents act as a hostage that S can use if B attempts to expropriate the value of S's customization efforts. B's hostage is the timing of the payment and the broad unilateral right to withdraw from the agreement. Note that the joint profit maximizing level of effort is given by $x^* = \arg\max\{V(x)—C(x)\}$, so that even with $k = 0$, the S's investment in customization in stage 1 is sub-optimal.

Finally, the two parties split the overall surplus so that

$$T_1 + T_2 - C(x,z) = ½(V(x) - C(x))$$

which implies that

$$T_1 = ½(V(x) - C(x,z)) - ½(1 - k)V(x) + C(x) = ½(kV(x) + C(x)) \tag{3}$$

We assume throughout that $x(k = 0) > 0$ so that strong enough patent protection will induce customization effort beyond the baseline level.[16]

Lemma 1: x is decreasing in k.

Proof. Obvious and omitted.

Choice of organizational form. Let $\Delta(k)$ represent the difference in joint surplus between independence and vertical integration, where x_1 represents the effort level under independence from (2).

$$\Delta(k) = [V(x_1) - C(x_1)] - [V(0) - C(0)] \tag{4}$$

It is easy to see that $\Delta(k)$ is non-negative because $V(x)—C(x)$ is increasing in x as long as x is less than the joint profit maximizing level, x^*. As noted earlier, since the stage 2 bargaining takes place after S's costs are sunk, this guarantees that x is always less than x^*. Since $x(k = 0) > 0$, it follows that as long as patents are stronger than some threshold

[16]Note further that if T_2, the second-stage payment, can be contracted for in advance and B can commit not to renegotiate, it will be set so that B is indifferent between ending the contract and making the payment, i.e. $T_2 = kV(x)$. In this case, for k small enough, $x = x^*$. This is formally shown in Arora (1996) and is similar to the result in Noldeke and Schmidt (1998). The outline of the proof is simple enough. Set $T_2 = (1 - k)V(x^*)$. For any $x < x^*$, B will end the contract, giving S a payoff of $-C(x)$. For $x > x^*$, B will make the payment, providing S with a payoff of $(1 - k)V(x^*) - C(x^*)$. Thus, S either chooses $x = x^*$ or 0. For k small enough, $(1 - k)V(x^*) - C(x^*) > -C(0)$, so that S chooses $x = x^*$.

level such that $x_1 > 0$, $\Delta(k)$ is strictly positive. Further, since, by Lemma 1, x is decreasing in k, so is $\Delta(k)$. Proposition 1 below summarizes this discussion.

> **Proposition 1:** (i) When there are no spillovers, independence yields (weakly) greater joint surplus. Independence is strictly preferred to integration when intellectual property rights are stronger than a threshold level. (ii) The stronger are S's intellectual property rights over the input technology, the greater the gain from independence.

3.2 Information spillovers

When S and B exchange information that can potentially lead to spillovers, firm independence results in rent dissipation (Teece, 1986). As before, under integration, S provides only baseline effort ($x = 0$) since it cannot appropriate for itself any of the benefits of additional effort.

If S and B are independent, information spillovers will not change the stage 2 bargaining since, by assumption, the rents from information spillovers are not affected by whether the two parties adhere to the contract, but only by whether the two parties exploit the information independently. This implies that T_2 is determined as before in (1). However, the choice of effort level affects the probability of information spillovers, and therefore, will be different if the firms are independent.

$$x = \arg\max\{½(1-k)V(x) - C(x) + p(x)\Pi^S\} \tag{2'}$$

$$T_1 = ½\{kV(x) + C(x) + p(x)\Pi^S\} \tag{3'}$$

Recall that synergistic spillovers are such that $\Pi^S = \Pi^S{}_\sigma > 0$ whereas under leakages, $\Pi^S = \Pi^S{}_L$ 0. It follows from (3′) that if x_σ is the optimal level of x under synergy and x_L under leakage, that a supplier has greater incentive to invest effort under synergistic spillovers, so that $x_\sigma > x_L$.

3.3 Organizational choice under information spillovers

As before let $\Delta(k)$ represent the difference between the joint surplus under independence and that under integration. The information spillover implies that this difference will have additional terms compared with equation (4) and can be written as

$$\Delta(k) = \{[V(x) - C(x)] - [V(0) - C(0)]\} + p(x)(\Pi^S) - p(0)\Pi \tag{5}$$

Letting $R = \Pi - \Pi^S$ represent rent dissipation, one can rewrite equation (5) as

$$\Delta(k) = \{[V(x) - C(x)] - [V(0) - C(0)]\} - p(0)R + [p(x) - p(0)\Pi^S \tag{5'}$$

The three terms in equation (5′) illustrate the fundamental tradeoff in organizational choice. The first term represents the *efficiency gain* when the firms are independent, due to superior customization effort by S (i.e. Firm S's superior capabilities). The second term represents the *rent dissipation* when the firms are independent. By assumption, $R = \Pi - \Pi^S$ is always positive so that the second term is always negative. It is easy to see that all else being the same, an increase in rent dissipation, R, will favor integration regardless of the nature of spillovers. This accords well with the 'firm capabilities' account of vertical integration. Finally, the third term measures the differential impact of information spillovers on effort under independence and integration. If spillovers are synergistic, this term is positive—an independent supplier invests greater effort in customization and hence increases the likelihood of additional value creation. Under leakages, this term is negative—an independent supplier runs a greater risk of its proprietary information leaking out.

Under synergies, the tradeoff between independence and integration is straightforward. Integration avoids rent dissipation but independence implies higher levels of customization effort. Higher customization effort has a direct benefit and an indirect benefit as well by increasing the probability of a positive stage 3 payoff from the synergistic creation of new knowledge. Under leakages, the tradeoff is more complicated. The superior customization effort from S when the firms are independent also increases the probability of negative payoff in stage 3.

One might suspect synergies favor firm independence and this is indeed the case. Let $\Delta(k)_\sigma$ represent the difference in joint surplus under independence and $\Delta(k)_L$ that under leakages.

$$\Delta(k)_\sigma - \Delta(k)_L = \{[V(x_\sigma) - C(x_\sigma)] - [V(x_L) - C(x_L)]\} + \{(p(x_\sigma) - p(0))\Pi^S{}_\sigma - (p(x_L) - p(0))\Pi^S{}_L\} \tag{6}$$

The first term in (6) is always positive because customization incentives for S are always higher under specialization. Formally, we have that $V(x) - C(x)$ is increasing in x and $x_\sigma > x_L$. The second term is also positive because $\Pi^S{}_\sigma > 0 > \Pi^S{}_L$ and $p(x_\sigma) > p(x_L) > p(0)$.

> **Proposition 2:** (i) The greater the rent dissipation, the lower the net surplus from independence relative to integration. (ii) The net surplus from independence is higher under synergistic information spillovers than under leakages. (iii) Under synergies, holding rent dissipation constant, increases in stage 3 payoffs increase the net surplus from independence.

3.4 Strength of intellectual property and organizational choice

Recall that absent information spillovers, stronger patents unambiguously favored firm independence. This conclusion is true *a fortiori* when information spillovers are synergistic, resulting in positive combined payoffs to the two parties in stage 3. To see this, note that from equation (5′) the first term is increasing in x, the second term is independent of x, and the third term is increasing in x if and only Π^S is positive, as is the case under synergistic spillovers. By proposition 1, x is decreasing in k. It follows that under synergies, the net benefit from independence is increasing in patent strength.

Under leakages, Π^S is negative so that the third term of (5′) is increasing in k, whereas the first term is decreasing in k. Although firm independence is favored because stronger patents provide stronger incentives for customization, this also increases the probability of negative stage 3 payoffs. Thus the impact of stronger patents on organizational choice is ambiguous under leakage.

This leads to a counterintuitive point: where leakage predominates, stronger patents may actually favor integration. In this case, the higher incentive for S to customize its input are partially offset by the greater threat of leakage of valuable information. Under the right conditions, B will decide to integrate S to avoid this result, even though this entails a loss in incentive intensity in adapting S's input to B's needs. In other words, the incentive to develop and deploy customization capabilities is too weak when Group S is constituted as Firm S. And so, integration.

> **Proposition 3:** With synergistic information exchange, stronger patent protection increases the joint surplus from independence relative to the joint surplus under integration. However, when information exchange results in leakage, the impact of stronger patents is ambiguous.

4. Changing tradeoffs: the role of buyout options and spinoffs

Noldeke and Schmidt (1998), writing from a property rights perspective, shows that firms sometimes employ 'buyout options' in supply contracts. This adds an incentive and policing component to the general observation that contracting parties show creativity in structuring transactions to maximize efficient exchange while conserving on transaction costs (Williamson, 1985). Options to buy can overcome many of the problems in a property rights-type (i.e. GHM) model with two sided non-contractible investments, provided the investments are observable and made sequentially. In essence, the option to buy recreates a residual claimant—the party moving second and holding the option. Our model is more specialized. We have assumed an input supply relationship where B is effectively the residual claimant in the input supply relationship. However, our result holds even if the buyout price is not contractible *ex ante*. Indeed we begin by analyzing the case where the buyout price is negotiated *ex post*.

If the B can buy the S after the new application is realized, then there is no rent dissipation under firm independence. In stage 3, with probability $p(x)$, B offers to buy out the S by paying T_3. The transaction takes place only if both parties agree to the transaction. Thus a buyout will take place only if $\Pi - T_3 \geq 0$ and $T_3 \geq \Pi^S$.[17]

Therefore, in stage 1, x is chosen as follows

$$x = \arg\max\{½(1-k)V(x) - C(x) + p(x)T_3\} \tag{2''}$$

It follows that x is higher with the buyout option than without. Further, since buyouts

[17] It is more natural to think of the synergy case here, unless one allows for S to pay B to be acquired so as to avoid harmful leakages.

obviate rent dissipation, the difference in the joint surplus under independence and integration, $\Delta(k)$ can be written as

$$\Delta(k) = \{[V(x) - C(x)] - [V(0) - C(0)]\} \tag{5''}$$

In other words, with buyout options, only the incentives for customization and openness matter. It also therefore follows that stronger patent protection always favors independence. From (5″) it is easy to see that decreasing k will increase x, implying that stronger patents make firm independence more attractive. It is easy to see that these conclusions hold even if T_3 is contracted for ex-ante and if B can unilaterally decide to exercise the buyout option. Proposition 4 summarizes these results:

> **Proposition 4:** If B can buy S out through mutual consent in stage 3, then independence dominates integration. Furthermore, stronger patents always raise the net surplus for independent firms regardless of the nature of spillovers.

> *Spinoffs.* Perceptive commentators such as Langlois (2003) have noted the significant trend toward vertical dis-integration in the world economy, without focusing explicitly on mechanisms of dis-integration. One important mechanism in this respect is the spinoff.

One can re-interpret our model as providing a simple theory of spinoffs. Consider the case where B owns S but before stage 1, can decide whether to spin it off as an independent firm. If it does so and endows S with the patents relating to the input technology, and only then enters into a contract for customization and input supply, this effectively corresponds to the choice of independent firms in our model. Proposition 3 would then predict that such a spinoff would take place if the input technology had strong enough patent protection, so that the benefits from greater customization effort by S outweighed the rent dissipation from the spinoff, particularly with synergies. Intuitively, the increased possibilities for synergy between S and various buyers of the input present attractive gains from trade that can only be realized by an independent, well-motivated S (Klepper and Sleeper, 1998). In addition, though we do not model it here, for a third party buyer of the input, the risk of leakage increases if S is a division of B: it is difficult to prevent the parent, B, from learning about the third party's manufacturing operations. Significantly, the management literature reflects both these advantages of spinoffs, as does the case of SepraChem discussed below.[18]

[18]Alster (1995: 49), describing advantages of spinoffs from established firms, and 'spinouts' from 'incubator' firms; Lepree (1995), SepraChem, spinoff from Sepracor, established to produce intermediate inputs for pharmaceutical industry, is exclusive licensee under 46 Sepracor patents; *Am. Petroleum Institute EnCompass Magazine* (1999), describing spinoff of specialty intermediate chemical firm from BP Amoco. For information on spinoffs in semiconductors, see Braun and MacDonald (1978: 121–145) and Malone (1985); for disk drives, see Chesbrough (1999).

5. A survey of the empirical evidence on patents and firm independence

The role of patents in facilitating arm's-length transactions in technology and technology intensive inputs is supported by recent research. In a study of 1612 licensing agreements, Anand and Khanna (2000) find that firms in industries characterized by weak rights are more likely to engage in non-licensing alliances such as joint ventures (see also Oxley, 1998, 1999). Weak IPRs also imply that technology developers are less likely to contract regarding to-be-developed technology (Anand and Khanna, 2000: 23). A study by Gans *et al.* (2000) of the commercialization strategies of 100 startup firms finds that when startups have robust IPR protection they are more likely to cooperate (i.e. license or contract) with incumbents. In contrast, when IP protection is weak startups are more likely to compete with incumbent firms by introducing competitive products. Hellmann and Puri (2000) found that startup firms that received venture capital were more likely to have patents, and had more patents, *ceteris paribus*, than other firms.

In a related vein, Arora *et al.* (2001) trace the connection between the tradition of well-defined patent rights and the highly active licensing market in the chemical industry. An empirical study of technology licensing contracts by Arora (1996) shows that patents are associated with the provision of technical services. Hall and Ham-Ziedonis (2000), in a general study of patents in the semiconductor industry, find that firms in the emerging semiconductor component industry are much more patent-intensive than other semiconductor firms of the same size but not developing components. They explain this by noting that these firms commercialize their technology only through licensing to large, often competitive firms that integrate components on a single 'system on a chip'. Thus where property rights are effectively weaker, the data suggest a resort to alternative appropriability mechanisms. Instead of straight arm's-length transfer, firms prefer (i) joint ventures and other alliance forms; and (ii) licenses to entities with whom they have had past relationships. Both of these are consistent with the proposition that stronger patents promote arm's-length transactions between independent firms.

Industry-level trends in fine chemicals and pharmaceutical intermediates lend additional support. In the past, chemical and pharmaceutical firms did very little outsourcing at the production stage. Now, however, the industry trade press describes significant growth in vertical supply transactions (*Chemical Market Reporter*, 1997; Gain, 1997). For instance, roughly 18% of pharmaceutical R&D funds goes to outsourcing now (*The Economist*, 1998: 16).

Outsourcing firms are a nexus for the development of chemical and pharmaceutical manufacturing technologies—technologies often covered by patents. According to the trade press, in a story about small firms specializing in optically pure or 'chiral' compounds:[19]

[19]Briefly, many molecules can exist in two mirror-image forms; they are said to be 'chiral'. The majority

> Patent developments are influencing the business strategies of custom manufacturers … [C]ustom manufacturers are seeking patent protection for novel processes and optically pure compounds . . . The hottest area for the development and patenting of chemicals is for chiral compounds . . . With many leading pharmaceuticals being chirals, custom manufacturers with expertise in asymmetric synthesis are benefiting . . . Industry analysts agree that process development is shaped by protection of intellectual property and costs. (Rose-Maniace, 1996)

The prevalence of this trend is confirmed by an informal survey of issued patents. Four outsource-manufacturing firms are mentioned in the *Chemical Market Reporter* (1997): Catalytica, Inc.; Lonza Corp.; ChemDesign, Inc.; and SepraChem, Inc. These firms have generated an impressive list of over 100 patents just since 1995. The vast majority of these patents are either process patents or patents on specific catalysts used as intermediates in chemical and pharmaceutical manufacturing.[20] And it is clear that firms believe their proprietary process technologies are a major selling point for the outsourcing industry.

Most of the companies specializing in chiral compounds, and in fine chemical outsourcing in general, must maintain a close working relationship with their customers. This is necessary to integrate the intermediate product sold by the input supplier into the overall manufacturing process of the large pharmaceutical client. Transactions in this industry have some common features of the contracts that we capture in our model: a first stage, where the supplier invests substantially in adapting its proprietary technology to the needs of a customer; a second stage, where intermediate products are sold; and a third, post contractual, stage, where learning from prior deals is applied.[21] Ownership of patents covering the design of its input products provides a supply firm with a reasonable fallback position in the event that future trades with the customer firm do not come through, a possibility that the financial disclosure documents of chiral suppliers explicitly note. There is good reason to believe that in chemical production outsourcing, the production firm's assets (patents) are what facilitate the customer-specific investments required to manufacture the customer's product.

There is evidence of the synergies described in our model. Supply agreements often

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of biomolecules occurring in the human body exist in only one of the two possible forms. Because the wrong chiral form can be ineffective or harmful (as in the case of the drug thalidomide), sophisticated catalysts are required to ensure that the manufacturing process for a pharmaceutical product yields only the desired form of the molecule. See generally Ball (1994: 77–78).

[20]See Arora and Merges (2001) for details on the patents.

[21]See Supply Agreement between Chirex, Ltd. and Cell Therapeutics, Inc., Exhibit 10.11, Chirex, Ltd., SEC Form 10K-405, filed November 14, 1998, available SEC EDGAR database; Supply Agreement between Glaxo Operations (UK) Ltd. and Chirex, Ltd., Chirex, Ltd. SEC FORM 8-K, filed September 23, 1997, Exhibit 10.13, available SEC EDGAR database.

include a license of the customer's technology to the supplier firm.[22] But the supplier firm does not assign its patents to the customer, and indeed there is usually not even a license from the supplier to the customer. And the supplier is free to build on its proprietary technology in the course of performing the supply contract.[23]

As expected, there is significant entry in this specialized niche as a consequence. Several established firms have entered this market through spinoffs (*Chemical Market Reporter*, 1997):

> In February of this year, the company [Boehringer] formed a separate business unit promoting its contract process development and manufacturing services for the pharmaceutical and related industries. The unit offers expertise including fermentation capacities for microorganisms as well as for cells of mammalian sources, extraction from animal and plant tissues, genetic engineering, protein refolding, and protein and enzyme technology.

Importantly, for the story being told here, these newly formed spinoffs are endowed with a portfolio of patents from the parent firm (Lepree, 1995). SepraChem, a spinoff from Sepracor, itself a specialist in chiral chemistry, was created to produce and commercialize intermediate inputs for the drug industry. SepraChem operates under licenses to Sepracor's proprietary technology, which includes 46 US patents for the synthesis of chiral intermediates.

Outsourcing in the chemical production industry thus exemplifies the thesis advanced here. Patents facilitate arm's-length trade of a technology-intensive input, leading to entry and specialization. This is part of a larger story in the chemical industry, in which firms adapt to the patent environment and patent protection in turn helps shape industry structure (Arora and Gambardella, 1998).

6. Conclusion

We have modeled the effects of property rights on the sourcing of information-intensive inputs. We feature a tradeoff: between integration, which avoids rent dissipation; and a freestanding input supply firm with property rights, which benefits from specialization through stronger incentives. This explains the viability of independent suppliers of information-intensive inputs—and hence, provides a rationale for investments in highly complementary 'firm capabilities' in these firms, along the lines of Teece (1988). We also show that, perhaps counter-intuitively, the advantages of independent firms increase when anticipated synergies are large. In other

[22] See Supply Agreement between Chirex, Ltd. and Cell Therapeutics, Inc. § 12.3, p. 15.

[23] See Supply Agreement between Chirex, Ltd. and Cell Therapeutics, Inc., § 12.4.2, p. 16: '[For all improvements,] if discovered, or learned of, by Chirex and not being specific to the Products, Chirex shall have the right to such improvements in relation to all products other than Products [covered by the Supple Agreement].'

words, when the future rents relate to a larger market, independence is more efficient. The intuition is that an increase in the rents increases the joint payoff to increasing the probability of beneficial synergistic creation of new information. The probability increases with supplier's efforts, which are higher when the supplier and the buyer are independent than if they are integrated. The gains can outweigh the rent dissipation from separate firms.

When synergies are anticipated, stronger property rights favor independence over integration. They provide higher incentives for an independent supplier, which has short run benefits in the form of a better adapted input, and longer term benefits in terms of greater likelihood of synergistic spillovers.

The model thus accounts well for the simultaneous emergence of stronger IPRs and various transaction-intensive organizational forms in industries where products are information-intensive.[24] We do not mean to argue that the tradeoff studied here is the only determinant of firm boundaries. As already noted, the firm capabilities perspective has highlighted the role of capabilities and of the nature of knowledge (e.g. Pisano *et al.*, 1988) in determining the boundaries of the firm in knowledge-intensive industries. In addition, two industry level factors deserve mention: (i) economies of scale and reduced duplication from specialized independent supply firms; and (ii) the beneficial role of independent supply firms in facilitating information exchange.

Conventionally, an independent suppplier has multiple customers for its input. This allows the usual Smithian or 'extent of the market' benefits; for example, there may be economies of scale in producing the input. There may be transactional economies of scale: Suppliers can be a central source for property rights relating to the input—either as owner or in a 'clearinghouse' role. This may reduce transaction costs related to fragmented ownership, also known as the 'anti-commons problem' (e.g. Heller, 1998). In addition, suppliers learn something from each customer. This information is aggregated in the hands of suppliers in a way it would not be if each producer used an integrated supplier. A supplier is thus in a position to embody in its offerings (at least some) 'best practice' information, in a manner quite familiar from the literature on specialized engineering firms in the chemical industry (Freeman, 1968; Arora and Gambardella, 1998). Put differently, independent supply firms may facilitate beneficial inter-firm information flows.

While the theory presented here is not a comprehensive theory of firm independence, it does extend our understanding of the role of IPRs beyond their role in providing incentives for innovation. Independent research-intensive suppliers are more viable at the margin when stronger patents are available. Patents make it possible to realize the effects of high-powered incentives. The combination of a property right and an arm's-length supply contract add up to greater efficiency. This is not to say that stronger patent protection comes without cost. For instance, Merges and Nelson (1990) point to the problems when excessively broad patents are granted on foundational

[24]On the growth of these organizational forms, see Grossman and Helpman (1999).

discoveries, especially in cumulative technologies where subsequent inventions build directly upon earlier ones. Others have pointed to the specter of stronger patents hurting innovation by creating an 'anti-commons' (Heller and Eisenberg, 1998).

Our intent is not to argue for stronger patent protection but rather to point out an insufficiently appreciated benefit. The mechanism we introduce goes beyond the conventional correlation between property right strength and incentives for invention. In our model, stronger property rights translate into greater incentives indirectly. State-backed property rights unleash the high-powered incentives of arm's-length contracting. Anticipating this, entrepreneurs are more likely to invest in supplier firms whose distinctive capabilities include superior innovativeness in a specialized technology.

Acknowledgements

We are grateful to a number of colleagues, and in particular, Andrea Fosfuri, Alfonso Gambardella, Jenny Lanjouw, Suzzane Scotchmer, Pablo Spiller, Oliver Williamson and two anonymous referees for helpful comments and suggestions. The customary disclaimers apply.

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References

Alster, N. (1995), 'Making the kids stand on their own,' *Forbes*, October 9, p. 49.

American Petroleum Institute (1999), 'BP Amoco transfers Topnir technology to Eutech,' *API Encompass News*, August 4.

Anand, B. N. and T. Khanna (2000), 'The structure of licensing contracts,' *Journal of Industrial Economics*, **48**, 103–135.

Arora, A. (1995), 'Licensing tacit knowledge: intellectual property rights and the market for know-how,' *Economic Innovation and New Technology*, **4**, 41–59.

Arora, A. (1996), 'Contracting for tacit knowledge: the provision of technical services in technology licensing contracts,' *Journal of Developmental Economics*, **50**, 233–256.

Arora, A. and A. Gambardella (1998), 'Evolution of industry structure in the chemical industry,' in A. Arora, R. Landau and N. Rosenberg (eds), *Chemicals and Long Term Economic Growth*. John Wiley & Sons: New York.

Arora, A. and R. Merges (2001), 'Property rights and information-intensive inputs,' mimeo.

Arora, A., A. Gambardella and A. Fosfuri (2001), *Markets for Technology: Economics of Innovation and Corporate Strategy*. MIT Press: Cambridge, MA.

Baker, G., R. Gibbons and K. J. Murphy (1997), 'Relational contracts and the theory of the firm,' National Bureau of Economic Research, NBER Working Paper 6177.

Ball, P. (1994), *Designing the Molecular World: Chemistry at the Frontier*. Princeton University Press: Princeton, NJ.

Braun, E. and S. MacDonald (1978), *Revolution in Miniature. The History and Impact of Semiconductor Electronics*. Cambridge University Press: Cambridge.

Chemical Market Reporter (1997), 'ChiRex sale of APAP business a move to focus on contracting,' June 2, 1997.

Chesbrough, H. (1999), 'Arrested development: the experience of European hard disk drive firms in comparison with US and Japanese firms,' *Journal of Evolutionary Economics*, **9**, 287–329.

Coase, H. (1937), 'The nature of the firm,' *Economica*, **4**, 386–405.

Cohen, W. M., A. Arora and J. P. Walsh (2003), 'Effects of research tool patenting and licensing on biomedical innovation,' in S. A. Merrill and W. M. Cohen (eds), *Patents in the Knowledge-Based Economy*, pp. 285–340. National Academies Press: Washington, DC.

Dosi, G. (1997), 'Opportunities, incentives and the collective patterns of technological change,' *Economics Journal*, **107**, 1530–1547.

The Economist (1998), 'Beyond the behemoths,' **346** (21 February), survey 16.

Freeman, C. (1968), 'Chemical process plant: innovation and the world market,' *National Institute of Economics Review*, **74**, 931–941.

Gain, B. (1997), 'Custom manufacturing takes off,' *Chemical Week*, May 14, S10.

Gallini, N. and R. Winter (1985), 'Licensing in the theory of innovation.' *Rand Journal of Economics*, **16**, 237–253.

Gans, J., D. Hsu and S. Stern (2002), 'When does start-up innovation spur the gale of creative destruction?,' *Rand Journal of Economics*, **33**, 571–586.

Grossman, G. M. and E. Helpman (1999), 'Incomplete contracts and industrial organization,' National Bureau of Economic Research, Working Paper 7303, August.

Grossman, S. J. and O. D. Hart (1986), 'The costs and benefits of ownership: a theory of vertical and lateral integration,' *Journal of Political Economics*, **94**, 691–719.

Ham-Ziedonis, R. and B. Hall (2001), 'The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979–1995,' *Rand Journal of Economics*, **32**, 101–128.

Handfield, R. B., D. R. Krause, T. V. Scannell and R. M. Monczka (2000), 'Avoid the pitfalls in supplier development,' *Sloan Management Review*, **41**, 37–49.

Hart, O. (1995), *Firms, Contracts, and Financial Structure*. Oxford University Press: Oxford.

Hart, O. and J. Moore (1990), 'Property rights and the nature of the firm,' *Journal of Political Economics*, **98**, 1119–1158.

Heller, M. A. (1998), 'The tragedy of the anticommons: property in the transition from Marx to markets,' *Harvard Law Review*, **111**, 621–688.

Heller, M. A. and R. Eisenberg (1998), 'Can patents deter innovation? The anticommons in biomedical research,' *Science*, **280**, 698–701.

Hellmann, T. and M. Puri (1999), 'The interaction between product market and financing strategy: the role of venture capital,' working paper, December, available at www.ssrn.com.

Kim, J. and G. Marschke (2001), 'Labor mobility of scientists, technological diffusion, and the firm's patenting decision', mimeo, available at http://papers.ssrn.com/paper.taf?abstract_id=288580

Klepper, S. and S. D. Sleeper (1998), 'Entry by spinoff: the evolution of the laser industry,' mimeo, Carnegie-Mellon University.

Langlois, R. N. (2003), 'The vanishing hand: the changing dynamics of industrial capitalism,' *Industrial and Corporate Change*, **12**, 351–385.

LePree, J. (1995), 'Fine chemical spinoffs set,' *Chemical Marketing Reporter*, **247**, January 14.

Malone, M. S. (1995), *The Microprocessor: A Biography*. Springer-Verlag: New York.

Masten, S. E. (1996), *Case Studies in Contracting and Organization*. Oxford University Press: New York.

McCutcheon, D. M., R. A. Grant and J. Hartley (1997), 'Determinants of new product designers' satisfaction with suppliers' contributions,' *Journal of Engineering Technology & Management*, **14**, 273–290.

Merges, R. P. (1996), 'Property rights theory and the commons: the case of scientific research,' *Social Philosophy & Policy*, **13**, 145–167.

Merges, R. P. (1999), 'As many as six impossible patents before breakfast: property rights for business concepts and patent system reform,' *Berkeley Technology Law Journal*, **14**, 577–615.

Merges, R. P., P. S. Menell and M. Lemley (2003), *Intellectual Property in the New Technological Age*, 3d edn. Aspen Law and Business: New York.

Merges, R. P. and G. H. Reynolds (2000), 'The proper scope of the patent and copyright power,' *Harvard Journal on Legislation*, **37**, 45–65.

Merges, R. P. and R. R. Nelson (1990), 'On the complex economics of patent scope,' *Columbia Law Review*, **90**, 839–916.

Noldeke, G. and K. M. Schmidt (1998), 'Sequential investments and options to own,' *Rand Journal of Economics*, **29**, 633–653.

Oxley, J. E. (1997), 'Appropriability hazards and governance in strategic alliances: a transaction cost approach,' *Journal of Law, Economics and Organization*, **13**, 389–407.

Oxley, J. E. (1999), 'Institutional environment and the mechanisms of governance: the impact of intellectual property protection on the structure of inter-firm alliances,' *Journal of Economic Behavior & Organization*, **38**, 283–309.

Pisano, G., W. Shan and D. Teece (1988), 'Joint venures and collaboration in the biotechnology industry,' in D. Mowery (ed.), *Technological Collaboration Ventures in US Manufacturing*, pp. 183–222. Ballinger: Cambridge, MA.

Pooley, J. (1999), 'Litigation and enforcement of trade secrets,' Practicing Law Institute publ. no. 574 PLI/Pat 619.

Ragatz, G. L., R. B. Handfield and T. V. Scannell (1997), 'Success factors for integrating suppliers into new product development,' *Journal of Product Innovation and Management*, **14**, 190–202.

Rose-Maniace, P. (1996), 'The rush to patent (special report: custom manufacturing '96),' *Chemical Marketing Reporter*, January 29, SR 6.

Sen, F. and A. H. Rubinstein (1989), 'External technology and in-house R&D's facilitative role,' *Journal of Product Innovation and Management*, **6**, 123–138.

Stuart, F. I. and D. M. McCutcheon (2000), 'The manager's guide to supply chain management,' *Business Horizons*, **43**, 35–44.

Stump, R. L. and J. B. Heide (1996), 'Controlling supplier opportunism in industrial relationships,' *Journal of Marketing Research*, **33**, 431–441.

Teece, D. J. (1986), 'Profiting from technological innovation: implications for integration, collaboration, and public policy,' *Research Policy*, **15**, 285–305.

Teece, D. (1988), 'Technological change and the nature of the firm,' in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds), *Technological Change and Economic Theory*. Pinter: London.

Teece, D. (1989), 'Inter-organizational requirements of the innovation process,' *Managerial and Decision Economics*, **10**, 35–42.

Teece, D.J., G. Pisano and A. Shuen (1997), 'Dynamic capabilities and strategic management,' *Strategic Management Journal*, **18**, 509–533.

US Federal Trade Commission (2003), *To Promote Innovation: The Proper Balance of Competition and Patent Law and Policy*. Federal Trade Commission: Washington, DC, available at http://www.ftc.gov/opp/intellect.

Valz, D. R. (2004), 'Strategic uses of intellectual property in the outsourcing of critical business functions,' in *Advanced Licensing Agreements 2004*. Practising Law Institute: New York.

von Hippel, E. (1994), ' "Sticky information" and the locus of problem solving: implications for innovation,' *Management Science*, **40**, 429–439.

von Hippel, E. (1988), *The Sources of Innovation*. MIT Press: Cambridge, MA.

Williamson, O. (1983), 'Credible commitments: using hostages to support exchange.' *American Economic Review*, **73**, 519–540.

Williamson, O. (1985), *The Economic Institutions of Capitalism*. Free Press: New York.

Williamson, O. (1996), *The Mechanisms of Governance*. Oxford University Press: New York.

Zeckhauser, R. (1996), 'The challenge of contracting for technological information,' *Proceedings of the National Academy of Sciences, USA*, **93**, 12743–12748.