Property Rights, Firm Boundaries, and R&D Inputs

Ashish Arora and Robert P. Merges

Carnegie-Mellon University; U.C. Berkeley

Contact: rmerges@law.berkeley.edu

Draft. Do not cite or quote without permission.

Abstract

This Article offers an explanation of the role of intellectual property rights (IPRs) in information-intensive vertical supply relationships. In particular, we explore the connection between stronger property rights and the enhanced viability of independent (versus vertically integrated) input supply firms when contracts are incomplete. We start by modeling a tradeoff between two types of information transfer in buyer-supplier relationships: "synergies," in which joint efforts reveal new applications of existing technology; and "leakage," or disclosure of existing information. We show that property rights in the hands of an independent input supplier can create the potential for greater inter-firm synergy, outweighing the risk of leakage. Greater synergies arise due to the supplier's greater effort to adapt its generalized technology to the specific needs of the buyer. Property rights play a crucial role: they reduce the risk of buyer firm opportunism, in effect raising the cost of the buyer's "outside option" in the event the supplier-buyer contract is terminated. The "residual" nature of property rights as described for example by Hart (1995) makes them more effective in this regard than contracts alone. We extend our basic results to analysis of buyouts and spinoffs, and assay an extensive body of empirical evidence. Broad support is found for our approach, pointing the way to future exploration of the relationship between property rights specifications and the opening up of new contracting horizons.

1.0 Introduction: The Story

This Article offers an explanation of the role of intellectual property rights (IPRs) in information-intensive vertical supply relationships. We analyze how IPRs affect the tradeoff between high-powered incentives and information spillovers, and show that under plausible conditions, they favor the provision of information intensive inputs by an independent supplier. Suppose a manufacturing unit MU has a specialized production process utilizing Input Q. Suppose further that Q is a technologically sophisticated component of MU's production process. In addition, Q is the unique specialty of scientists and engineers who comprise research unit RU. One way for MU to get the input is to employ RU – vertical integration. In the alternative, members of RU could found an independent firm to supply Q in an arm's-length contract with MU.

In making its decision, MU faces a well-recognized tradeoff pitting the possibility of opportunism against high-powered arm's-length contracting (Coase, 1937; Williamson, 1996). The effort invested in customizing Q may be non-contractible so that RU may shirk. On the other hand, once expended, the effort is sunk, leaving RU vulnerable to reneging by MU. This is a familiar tradeoff in the literature of transaction cost economics. But the details of our story, drawn from the information-rich exchanges we describe, add some important theoretical twists, as formalized in section 2. In supplying Input Q, RU will have to interact extensively with the staff of MU. This entails considerable information exchange. In general, the information in this relationship is of two types: (1) *leakage* of pre-existing information held by each party; and (2) *synergistic generation* of new information. Leakage is straightforward: there is almost always information exchange in supplier-buyer transactions; this is particularly true where MU's

production process and RU's input are technologically complex.[1] 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 (MacLachlan, 1995). 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). These are of course purely informal measures. But they do indicate that the issue is a real one.

Synergistic generation of new information is also very common in the kinds of input transactions studied here. The empirical basis is presented in section 3, where we discuss the property rights allocations and contractual provisions real-world parties often craft to deal with leakages and synergies. In general, RU-MU interactions can generate useful information about potential new applications of Input Q, perhaps in the production of other products besides the one contemplated by the original contact. Or RU may learn about opportunities to add to the Input Q product line. For example, it might learn of a way to expand Input Q's functionality to replace other inputs in MU's production process.[2]

[1] R&D Managers are well aware of this problem. See, e.g., Ragatz, Handfield and Scannell (1997: 199) (noting fear of information sharing in new product development outsourcing agreements); Stump and Heide (1996) (describing techniques for "controlling supplier opportunism."). For a good overview, see Handfield, Krause, Scannell and Monczka (2000).

[2] Management literature shows an awareness of these opportunities for synergy. Stuart and McCutcheon (2000: 35) ("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, Grant and Hartley (1997: 275) (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."); Ragatz, Handfield and Scannell (1997: 200) (summarizing industry experience integrating suppliers into new product development, and finding that the greater the sharing of "intellectual assets" among the partners, the greater the degree of success of the product. 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"; and (1989: 125) note that "flowback [i.e., grantback] clauses may be necessary in outsourcing contracts because of the likelihood that the parties may "improve the acquired technology" during an outsourcing agreement.

These two types of information spillovers – leakage and synergies – are at the heart of the tradeoff modeled in this Article. By choosing to integrate (i.e., by owning RU), MU prevents leakage of information about its products and processes. Greater control over disclosure of internal information is a well-recognized feature of the employment relationship, as compared to independent contractor status (Masten, 1996). In addition, the law by default vests a firm with ownership of employee inventions, thus allocating to the employer the residual that accompanies ownership of property rights (Merges, 1999). Integration also internalizes the benefits of synergistic information. In the absence of integration, both RU and MU may base future products on the information generated in the supply relationship. Or they may compete in the market for this information per se, as rival licensors. In either case, (some of) the rents made possible from the new information will be competed away.[3] As the literature on technology pioneers and improvers shows, integration prevents rent dissipation (Scotchmer, 1991).

On the other side of the ledger, an independent RU has certain information-related advantages. One is obvious: the canonical "high-powered incentives" that flow from arm's-length contracting. This leads in turn to a second, more particular to our context: RU's increased efforts create more synergistic information. The combination of independence and property rights over synergistic information induces RU to work hard to expand the frontiers of Input Q. New applications and extensions of the technology become more likely. Because an independent RU can directly appropriate the value of the new applications, RU team members will work harder to uncover them.[4] Further, though we do not model it, an independent RU can aggregate

[3] The management literature shows a sophisticated awareness of these issues. See, e.g., Leavy (1994, 1996). For example, Leavy (1996: 50) states: "Even in the closest of outsourcing relationships, the partners will always remain potential future competitors.")

[4] Practitioners recognize this. Michael A. Corbett Associates (2000):

> When organizations are not changing they favor internal sourcing. Similarly, when they view the internal operation as highly innovative they also favor internal sourcing. However, when there is a

information across supply relationships, thus gaining a "multiplier effect" for each unit of synergistic information.

The emphasis on information in this Article represents a departure from prior treatments of vertical integration. Transaction cost economics (TCE) first called attention to the high-powered incentives of arm's-length contracting. TCE incentives take the form of a more direct relationship between effort and profit, with no mention of informational synergies. On the other hand, the discussion of integration in this Article is closer to TCE. Preventing information leakage is closely related to the core TCE concern of integrating to reduce opportunism. It might also be argued that competing for rents from synergistic information is a form of opportunism. To the extent it is not, this Article extends current thinking by introducing rent dissipation as an explicit factor influencing vertical integration.

The ideas in this Article are close to the spirit of the property rights-firm boundaries literature (Grossman and Hart, 1986; Hart and Moore, 1990; Hart, 1995) ("GHM"), but not identical. While the model here is concerned with the allocation of property rights in facilitating more efficient sequential investment, fewer restrictive assumptions are employed. For example, we avoid GHM's exclusive emphasis on the strictly marginal effects of property rights allocations (Holmstrom and Roberts, 1998: 79). In addition, we explicitly consider "post-contractual" benefits arising from supply relationships – i.e., learning that has value in periods beyond those in simple two-stage models of investment and asset transfer. Most importantly, in this Article property rights specifications are not assumed to be fixed; patent strength is an explicit variable in the model. This permits more robust exploration of the relationship between features of the property rights regime and the "make versus buy" decision.

---

recognized need for change and when the internal group cannot or is not viewed as being capable of bringing forward the needed changes, then external sourcing becomes the preferred option.

The approach here thus has some similarity to Zingales and Rajan (1998), whose concept of "access" to assets introduces a more nuanced interpretation of property rights. This Article pays particular attention to R&D-intensive inputs that do not often meet the conditions of their model, however. Finally, the bargaining between pioneers and improvers (Scotchmer, 1991) has some similarity to that between input suppliers and manufacturers (e.g., RU and MU). In both cases, multiple contributors together generate new, complementary information. And in this Article, as in Scotchmer (1991: 35), integration has the advantage of preventing rent dissipation. In the pioneer-improver scenario, however, ex ante bargaining is often impossible. Many improvement patents are owned by firms that had no opportunity to negotiate with the pioneer, often because lags in the patent system make it difficult to determine which of two parties will end up the pioneer, and which (if any) the improver (Merges, 1994). By contrast, suppliers of information-intensive inputs must negotiate with manufacturers ex ante. Indeed, in our model, synergistic information cannot be generated in the absence of RU-MU interaction. Thus our model analyzes the effects of rent dissipation identified in the pioneer-improver literature in a setting where ex ante bargaining is a necessary part of the situation.

2.0 The Model

Let V(X) be the benefit to the MU from the purchase of the specialized input, where X represents the stage 1 effort by RU to customize the input, at a cost C(X, Z), where Z is the level of openness chosen by MU. We assume that $X \in [X^{min}, X^{max}]$, where X^{min} is a baseline level of effort which can be verified. Similarly, we assume $Z \in [Z^{min}, Z^{max}]$. We further assume efficient bargaining. Thus, whether MU chooses to integrate RU or not depends on which form yields the greatest joint surplus. We assume that V(X) and C(X, Z) increasing and concave in X, and C(X, Z) and $C_x(X, Z)$ are both decreasing in Z, where $C_x(X, Z)$ represents the marginal cost of

customization. In other words, openness by MU reduces the marginal cost of customization by increasing the flow of information to RU. For simplicity, we assume that openness has no direct costs for MU, though a more realistic situation would be to assume that controlling information flow is costly for MU.[5]

The process of customizing an input will require information flows between RU and MU. As noted earlier, such flows can have two types of consequences. They can reveal valuable information about RU to MU and vice versa. If both MU and RU are part of the same firm, leakage of proprietary information is of no consequence. However, if they are independent firms, RU may be able to use the information in ways that reduce MU's rents. For instance, it may reveal this information to MU's rivals, or embody it in services it provides to MU's rivals. In sum, this leakage may lead to a partial dissipation of rents. In principal, the situation is symmetric. MU may likewise use what it learns from RU. It is less likely, albeit not impossible, that MU would use what it learns to compete, directly or indirectly, with RU, thereby also dissipating rents.[6] Insofar as this usage does not result in rents being dissipated, one can simply think of this as an additional cost to RU, subsumed under C(X, Z). We only analyze the case where RU may use what it learns to compete with MU.

Information exchange can also lead to the synergistic creation of new information. Because only an independent RU has an incentive to work hard to reveal new information, dis-integrating RU from MU can unlock significant potential value. New applications and extensions

[5] Trade secret law protects information only upon a showing of "reasonable precautions" against disclosure, such as costly monitoring and sequestering. *See, e.g.*, Rockwell Graphic Systems, Inc. v. DEV Industries, Inc., 925 F.2d 174 (7th Cir. 1991) (Posner, J.). For a descriptive account of such "fencing costs," see Merges et al. (2000: 49).

[6] Handfield, (2000: 40):

> One of the biggest challenges in supplier development is cultivating mutual trust. Suppliers may be reluctant to share information on costs and processes; the need to release sensitive and confidential information may compound this hesitation. Ambiguous or intimidating legal issues and ineffective lines of communication also may inhibit the trust building necessary for a successful supplier-development effort.

of the technology may be revealed.[7] We model this as follows. After the customization is completed, with probability P(X, Z), MU and RU receive payoffs of Π_M and Π_R, and with probability 1-P(X,Z) MU receives a payoff of W and RU a payoff of zero. Here W represents the rents that MU would earn if information exchange did not result in leakage of information or the synergistic creation of new information. In the leakage case, we have $W > \Pi_{M;}$ with synergy, $\Pi_M > W$. If both MU and RU are part of the same firm, then the combined entity receives a payoff of Π with probability P(X, Z). Rents are dissipated if $\Pi > \Pi_M + \Pi_R$. Under synergy, $\Pi > W$, but in the leakage case, $\Pi = W$.[8] Clearly, these are not mutually exclusive possibilities. Information exchange is likely to reveal proprietary information that is the source of existing rents, as well as lead to the creation of new and useful information, which in turn may be the source of additional rents. Extending our model to accommodate both leakage and synergy is straightforward.

The timing and structure of the game is as follows: RU begins the game with a property right (i.e., patent) over the general design of its input. If RU and MU are part of the same firm, the property rights belong to the firm as a whole. After the initial contract details are settled, RU and MU choose levels of X and Z respectively. We assume that neither X nor Z are contractible, but both MU and RU can observe the levels of X and Z. MU may also make a transfer payment to RU. The role of this first stage payment, T_1, is essentially to divide the total surplus between the two. This concludes stage 1 of the game. In stage 2, RU and MU negotiate second stage payments, T_2. At this point, both X and Z are "sunk," thus opening the door to potential holdup problems. In stage 3, which is unique to our model, the information flows result in spillovers

[7] To the extent that only RU becomes aware of the new application, this is formally equivalent to a reduction in cost, C(X, Z), and likewise, if only MU becomes aware of the new application, this is equivalent to an increase in V(X).

[8] Note that $\Pi_M > W$ defines synergy whereas $\Pi = W$ defines leakages. It is clear that these cases are mutually exclusive. However, they are not exhaustive i.e., we are ruling out by assumption the case where $\Pi > W$ and $\Pi_M < W$, where information exchange always leads to a loss for MU but a net social gain.

with probability P(X, Z). This 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 RU and MU. We assume that an independent RU and MU may not contract not to compete with each other in stage 3, implying rent dissipation in stage 3.

To highlight the role played by patents, we first analyze the special case when stage 3 is absent. We demonstrate that patents can make possible contracts where an independent RU invests in customization.

2.1 Special Case: No spillovers

Specialization (RU is independent)

Once the investment is sunk, the parties bargain over the payment MU must make to RU. We assume the bargaining results in an equal split of the surplus defined by the "threat points" of the two parties. MU can threaten to end the relationship. Should it do so, RU will withdraw its input. After termination, MU would be able to duplicate RU's design of the input, or transfer the RU design to a third party supplier, getting a net benefit of L(X). Here we assume that the ability of MU to produce the input for itself may benefit from the effort RU makes in customizing the input, and the disclosure of information by RU in the process of customizing the input.[9] The joint profit maximizing level of effort is given by X^{OPT} = argmax {V(X) – C(X, Z)}, so that even with L(X) = 0, the RU's investment in customization in stage 1 is sub-optimal.

If T_2 is the second stage payment, then we have

$$T_2 = \text{argmax} \quad (V(X) - T_2 - L(X))^{1/2} (T_2)^{1/2} \qquad (1)$$

[9] MU learns from RU 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 RU is a software supplier, for example, it could supply MU either with finished computer code to be directly incorporated into MU's own end-user software product, or

so that

$$T_2 = \tfrac{1}{2}(V(X) - L(X)) \qquad (2)$$

Knowing this, in stage 1, RU chooses X to maximize $T_2 - C(X, Z)$. MU chooses Z to maximize $V(X) - T_2$. Since we assume Z has no direct cost, the choice of Z is indeterminate. We assume that MU will choose $Z = Z^{max}$.[10] The joint surplus is $V(X^S) - C(X^S, Z^{max})$ where X^S is the effort level chosen by RU. It is easy to see that T_1 is given by

$$T_1 = \tfrac{1}{2}(V(X) + C(X, Z)) - \tfrac{1}{2}(V(X) - L(X)) = \tfrac{1}{2}(L(X) + C(X, Z)) \qquad (3)$$

This is the point where RU's patents play a role. RU's patent on the general design of its input implies that if MU had to "invent around" RU's patents, L(X) would be lower than V(X). In this sense, the level of L(X) is inversely related to the effectiveness of intellectual property protection. This formulation is similar to the one used in Gallini (1985) and Arora (1995; 1996). For analytical convenience, we assume that L(X) = kV(X), where $k \in [0, k^{max}]$, $k^{max} \leq 1$. A decrease in *k* corresponds to an increase in the "strength" of patent protection. Thus, one can write the choice of X as

$$X^s = \arg\max \tfrac{1}{2}(1 - k)V(X) - C(X, Z) \qquad (4)$$

We assume throughout that argmax $\{\tfrac{1}{2}(1- k^{min}) V(X) - C(X, Z^{max})\} > X^{min}$, so that strong enough patent protection will induce customization effort beyond the baseline level.[11]

---

with "high level" design information on how to achieve a particular software objective. We assume only that the input supplied by RU has a high degree of information content.

[10] This would be true if, for instance, MU could move earlier or could commit. This would also be true if we added a small component to V(X) that was increasing in Z.

[11] Note further that if $T_{2,}$ the second stage payment, can be contracted for in advance and MU can commit not to renegotiate, it will be set so that MU is indifferent between ending the contract and making the payment, i.e., $T_{2,} = L(X) = kV(X)$. In this case, for *k* small enough, $X = X^{OPT}$. 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 $T_2 = (1-k)V(X^{OPT})$. Now for any choice of $X < X^{OPT}$, MU will end the contract, giving RU a payoff of $-C(X, Z)$. For $X \geq X^{OPT}$, MU will make the payment, providing RU with a payoff of $(1-k)V(X^{OPT}) - C(X,Z)$. Since C(X,Z) is increasing X, the RU either chooses $X = X^{OPT}$ or X^{min}. For *k* small enough, $(1-k)V(X^{OPT}) - C(X^{OPT}, Z) > -C(X^{min},Z)$.

Lemma 1 $X^S(k)$ is decreasing in k. Further, $X^S(k^{max}) = X^{min}$.

Proof Obvious and omitted.

Vertical Integration

Under vertical integration, the MU (more precisely, the combined entity) owns the inputs and any associated intellectual property rights and RU cannot withdraw its inputs in the event of a disagreement. Accordingly, it has no incentive to invest effort beyond the baseline level X^{min}. As before, technically the value of Z is indeterminate but we assume that it is set to Z^{max}.

Let $\Delta(k)$ represent the difference in joint surplus between specialization and vertical integration is $[V(X^S) - C(X^S, Z^{max})]- [V(X^{min}) - C(X^{min}, Z^{max})] > 0$. Since X^S is decreasing in k, so is $\Delta(k)$. Proposition 1 below summarizes this discussion.

Proposition 1 *When information spillovers do not exist,* (i) *The stronger RU's intellectual property rights over the input technology, the greater RU's efforts at customization. However, RU's efforts are always below the joint profit maximizing level.* (ii) *Specialization is weakly more efficient than vertical integration. If RU's input technology is not patented, both organizational forms yield the same joint surplus. The stronger are RU's intellectual property rights over the input technology, the greater the gain from specialization.*

2.2 Information Spillovers

With information spillovers, vertical integration prevents rent dissipation. Further, the existence of spillovers will not change the stage 2 bargaining since, by assumption, the spillovers are not affect by whether the two parties adhere to the contract, but only by whether the two parties can independently exploit the information spillovers. If the probability of such spillovers

were exogenously set at $\overline{P}$, the nature of the spillovers (leakage or synergy) would be irrelevant, and the levels of X and Z would be identical to those without spillovers. The difference in the joint surplus Δ is given by

$$\Delta = [(V(X^S) - C(X^S, Z^{max})) - (V(X^{min}) - C(X^{min}, Z^{max}))] - \overline{P}\ (\Pi - \Pi_M - \Pi_R). \qquad (5)$$

The two terms represent the trade-off between specialization and integration in our model. The first term represents the benefits from the superior incentives possible under specialization. It is non-negative since $X^S \geq X^{min}$. The second term represents the loss (compared to integration) from rent dissipation. Therefore Δ is no longer unambiguously positive as it now involves a tradeoff between greater surplus from customization and rent dissipation. Whereas the surplus from customization is increasing in the strength of RU's patents, rent dissipation is not. Thus, as long as the rent dissipated is strictly less than the maximum potential surplus from customization, specialization yields greater joint surplus for intellectual property rights stronger than some threshold value. Formally, we have

Lemma 2 $P(X, Z) \equiv \overline{P}$ and $[V(X^{opt}) - C(X^{opt}, Z^{max})] - [V(X^{min}) - C(X^{min}, Z^{max})] > \overline{P}\ \{\Pi - (\Pi_M + \Pi_R)\}$, implies that there exists $k^* \in [0, k^{max}]$ such that $k < k^*$ implies $\Delta > 0$.

Proof Let $\Delta(k) = [V(X(k) - C(X(k), Z^{max})] - [V(X^{min}) - C(X^{min}, Z^{max})] - \overline{P}\ \{\Pi - (\Pi_M + \Pi_R)\}$. Note that $X(0) = X^{opt}$, and $X(k^{max}) = X^{min}$. Thus, $\Delta(0) > 0$ and $\Delta(k^{max}) < 0$. By continuity, there exists $k^* \in [0, k^{max}]$ such that $\Delta(k^*) = 0$. Since $\Delta(k)$ is decreasing in k, $k < k^*$ implies $\Delta(k) > 0$

In general, the probability of spillover would depend on the level of effort by RU and the level of openness allowed by MU. This provides an additional source of incentive for customization by an independent RU, because greater customization effort increases the probability of RU earning additional rents through information spillovers. Thus RU's property

right can lead, indirectly, to greater customization: by preventing MU opportunism at stage 2, the property right encourages more investment in customization at stage 1, and therefore leads to higher spillovers in the post-contractual period, stage 3.

Specialization

Under specialization, however, the nature of the spillovers matter as well: MU will not choose to be fully open, if by doing so it increases the probability of a leakage resulting in a loss. Formally, the choice of X and Z are given by (6).[12]

$$\begin{aligned} Z^s &= \arg\max\{\tfrac{1}{2}(1+k)V(X) + W + P(X, Z)(\Pi_M - W)\} \\ X^s &= \arg\max\{\tfrac{1}{2}(1-k)V(X) - C(X, Z) + P(X, Z)\Pi_R\} \end{aligned} \qquad (6)$$

Recall that if the spillover consists of a leakage of existing information, $\Pi_M - W < 0$. Since P(X, Z) is increasing in Z, MU will choose the lowest possible level of openness, Z^{min}. Therefore, if X_L^s represents the choice of X under specialization and leakages,

$$X_L^s = \text{argmax}\ \{\tfrac{1}{2}(1-k)V(X) - C(X, Z^{min}) + P(X, Z^{min})\ \Pi_R\}. \qquad (7)$$

However, if spillovers create synergies, $\Pi_M - W > 0$, so that MU will choose the highest level of openness, Z^{max}. If X_s^s represents the choice of X under specialization and synergy,

$$X_s^s = \text{argmax}\ \{\tfrac{1}{2}(1-k)V(X) - C(X, Z^{max}) + P(X, Z^{max})\ \Pi_R\}. \qquad (8)$$

Under both types of spillovers, RU will receive a positive payoff, the probability of which is increasing in RU's customization efforts. Consequently, spillovers enhance RU's incentives to invest effort. Further, RU's effort increases as Π_R increases. Thus, even with weak patents, RU may provide customization effort. The level of this incentive does depend on the type of spillover. Even if RU were to receive the same level of payoff in both cases, the greater

openness by MU under synergies will result in greater effort by RU. (Recall that greater openness by MU reduces the marginal cost of customization to RU.)[13]

Integration

Under integration, the choice of X and Z are given by (9).

$$\begin{aligned} Z^I &= \text{argmax} \quad \{V(X) + W + P(X, Z)(Đ - W)\} \\ X^I &= \arg\max \{-C(X, Z)\} \end{aligned} \tag{9}$$

Thus, RU will provide the baseline level of effort, X^{min}, and MU will choose the maximium level of openness, Z^{max}. Under synergies, this is the unique outcome, since $\Pi > W$. Under leakage, the chosen level of openness is indeterminate because $\Pi = W$ under leakage. However, as before, we assume that when indifferent, MU chooses the maximum level of openness. Thus, under leakages, specialization implies an additional source of inefficiency because MU will not allow free flow of information, resulting in higher customization cost and lower customization effort, albeit also a lower probability of rent dissipation. Proposition 2 summarizes these results

Proposition 2 *With information spillovers,* (i) *RU's effort is higher than in the absence of spillovers and increases with the spillover rents to RU, ceteris paribus. RU's efforts also increase in the strength of RU's patents.* (ii) *MU chooses the maximum (minimum) level of openness under synergy (leakage).* (iii) *Ceteris Paribus, RU's effort is higher under synergy than under leakage.*

The difference in the joint surplus between specialization and integration under leakages,

[12] Since we assume that the choices are made simultaneously, $\{X^s, Z^s\}$ is the set of Nash Equilibria characterized by (6). It is easy to see that as long as a unique Nash Equilibrium exists generically.

is represented by $\Delta(k)_L$ and $\Delta(k)_s$ represents the difference under synergy.

$$\Delta(k)_L = [V(X_L^s - C(X_L^s, Z^{min})] - [V(X^{min}) - C(X^{min}, Z^{max})] + P(X_L^s, Z^{min})(\Pi_M + \Pi_R - \Pi) \quad (10a)$$

$$\Delta(k)_s = \{[V(X_s^s - C(X_s^s, Z^{max})] - [V(X^{min}) - C(X^{min}, Z^{max})]\} + P(X_s^s, Z^{max})(\Pi_M + \Pi_R) - P(X^{min}, Z^{max})\Pi \quad (10b)$$

The first two terms of (10b) are decreasing in k since X_s^s is decreasing in k. Moreover, the last term is independent of k, so that $\Delta(k)_s$ is decreasing in k. Thus, by an argument similar to proposition 2, for patent strength stronger than some threshold value, specialization yields a higher surplus. However, $\Delta(k)_L$ cannot be unambiguously signed because the third term in (10a) is increasing in k. Although X_L^s is decreasing in k, $(\Pi_M + \Pi_R - \Pi)$ is negative. Stronger patent rights for RU, by increasing the incentives for customization effort, also increase the probability of rent dissipation. Therefore, specialization may yield a lower surplus when RU's intellectual property rights are strong.

Holding the extent of rent dissipation constant, as one increases the size of the total rents from information spillovers, $\Delta(k)_s$ increases. To see this rewrite (10b) as follows

$$\Delta(k)_s = [V(X_s^s - C(X_s^s, Z^{min})] - [V(X^{min}) - C(X^{min}, Z^{max})] - P(X_s^s, Z^{max})R + \Pi(P(X_s^s, Z^{max}) - P(X^{min}, Z^{max})) \quad (11)$$

where $R = (\Pi - \Pi_M - \Pi_R)$ is the extent of rent dissipation.

Holding rent dissipation, R, constant, an increase in the size of the rents from spillovers, Π, will increase $\Delta(k)_s$ because the coefficient of Π in (11), $P(X_s^s, Z^{max}) - P(X^{min}, Z^{max})$ is

[13] Note that even under synergies, $X^s_s < X^{opt} = \{\arg\max V(X) - C(X, Z^{max}) + P(X, Z^{max})\Pi\}$, and that X^s_s is decreasing in k.

positive.[14] On the other hand, an increase in the size of the spillover rent but holding the rent dissipation constant will leave $\Delta(k)_L$ unchanged. Proposition 3 summarizes these results.

Proposition 3: (i) *With synergistic spillovers, specialization is preferred to integration if patent protection is stronger than a threshold level.* (ii) *An increase in the size of the spillover rents increases the surplus under specialization by more than (equal to) the surplus under integration with synergistic spillovers (leakages).*

2.3 Changing Tradeoffs: The Role of Buyout Options and Spinoffs

A recent paper by Noldeke and Schmidt (1998) shows that options to buy can overcome many of the problems in a 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 effectively MU is the residual claimant of the value created through the input supply.

Providing MU with an option to buyout RU does, however, increase efficiency under specialization. It eliminates rent dissipation, which is the drawback with an independent RU. Indirectly, this also increases incentives for an independent RU because it is in MU's interests to offer a buyout price that is at least as high as Π_R. This suggests that allowing MU the option to buyout RU when spillovers occur implies that specialization yields a greater joint surplus than integration. Under these conditions, an option to purchase (a controlling interest in) RU may make sense ex ante. This solution combines the immediate benefits of high-powered incentives

[14]Here we allow Π and Π_M to increase by the same amount. If we allow Π_R to increase of Π_M, this would increase RU's effort under both types of spillovers, increasing the surplus under specialization relative to integration.

from asset ownership and contracting with the contingent payoff scheme of Noldeke and Schmidt (1998). We formalize this intuition in the appendix and show that this is true even if, under integration, RU threatens to break away from MU. Further, unlike Noldeke and Schmidt (1998), the result does not depend on the buyout price being negotiated in advance.

Discussion

One can re-interpret our model as providing a simple theory of spinoffs as well. Consider the case where MU owns RU but before stage 1, can decide whether to spin it off as an independent firm. If it does so and endows RU with the patents relating to the input technology, and only then enters into a contract for customization and input supply, this effectively corresponds to specialization in our model. Proposition 3 would then predict that such a spin-off would take place if the input technology had strong enough patent protection, so that the benefits from greater customization effort by RU outweighed the rent dissipation from the spin-off, particularly if the spillovers were synergistic. Section 3 includes discussion of SepraChem, a Sepracor spinoff, that supports this story.

The tradeoff between an independent RU and an integrated MU-RU firm is primarily a function of three factors: the amount of incontractible investment required to tailor RU's input to MU; the risk of leakage from MU to RU; and the potential for synergistic gains from the RU-MU relationship (which incorporates RU's potential future profits from exploiting its share of the synergistic gains). Firms might anticipate that ex ante, the better decision is to permit RU to remain independent. However, the parties might also anticipate proprietary information might leak out or that the technology could develop so as to expose MU to greater risk of competition from RU, or so as to lower the implicit costs of integration (e.g., by making the technology more

predictable, thus permitting more credible performance-pay contracts for researchers). Under these conditions, an option to purchase (a controlling interest in) RU may make sense ex ante.

On the other hand, a research project that grows naturally out of MU's integrated research division may present opportunities for efficiency gains if it is "spun out" into an independent firm (Klepper and Sleeper, 2000). Intuitively, the increased possibilities for synergy between RU and various buyers of Input Q present attractive gains from trade that can only be realized by a well-motivated (i.e., independent) RU. In addition, though we do not model it here, for a third party buyer of Input Q, the risk of leakage increases if RU is a division of MU: it is difficult to prevent the parent, MU, from learning about the third party's manufacturing operations. Significantly, the management literature reflects both these advantages of spinoffs.[15].

Although in this Article the connection between buyouts, spinoffs, and property rights is somewhat speculative, note that ownership of a research partner's IPR portfolio is often a crucial factor motivating buyouts, and spinoff firms appear always to be set up with a viable portfolio of IPRs of their own. Again, the SepraChem spinoff story in section 3 is an example.This suggests that property rights considerations permeate integration decisions, even contingent ones.

3. Empirical Support

This section examines empirical evidence for the theory. Three types of evidence are adduced: (1) empirical studies tracing industry-level connections between IPR strength and the volume of licensing; (2) a summary of specialized input suppliers and their patents in the fine

[15] 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, pp. 121-145), and Malone (1985); for disk drives, see Chesbrough (1999).

chemical and pharmaceutical industries; and (3) a case study of one transaction, between a technology-intensive input supplier and a large bio-pharmaceutical firm.

The role of patents in facilitating arm's-length transactions in technology is supported by the findings of Anand and Khanna (1997). In a study of 1612 licensing agreements, Anand and Khanna (1997) find that weak IPRs are associated with a lower incidence of licensing activity, especially with respect to "prospective" (to-be-developed) technologies. A key finding of the study is that in industries where IPRs are important, licensing, as a percentage of all alliances, is much more frequent than in other industries.[16] In the IP-intensive chemical-related industries, approximately 1/3 of the alliances are licenses, whereas licenses constitutes only 18% and 24%, respectively, of the alliances in computers and electronics (Anand and Khanna, 1997: 17).

Transfers of technology do take place even in industries where IPRs are weak. The nature of the transactions differ, however. Firms in industries characterized by weak rights are more likely to engage in non-licensing alliances such as joint ventures (Oxley, 1998, 1999; Anand and Khanna, 1997: 16-23). They are also less likely to contract regarding to-be-developed technology (Anand and Khanna, 1997: 23). A recent study by Gans, Hsu and Stern (2000) of the commercialization strategies of 100 startup firms finds that when startups have robust IPR protection, and when they have venture capitalists backing them, they are more likely to cooperate (i.e., license or contract) with incumbents. In contrast, when IP protection is weak, and when venture capitalists are not involved, startups are more likely to compete with incumbent firms by introducing competitive products. Hellmann and Puri (2000) found that startup firms

[16] Numerous studies document differences in the strength of intellectual property protection across various industries. In particular, patents are known to be most effective in chemical industries. They are widely thought significantly less effective in computers, electronics, and related fields (Merges and Nelson, 1990, citing Levin et. al. 1986).

that received venture capital were more likely to have patents, and had more patents, *ceteris paribus*, than other firms.

In a related vein, Arora, Fosfuri and Gambardella (2000) trace the connection between the tradition of well-defined patent rights and the highly active licensing market in the chemical industry. 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 (1) joint ventures and other alliance forms, and (2) licenses to entities with whom they have had past relationships. Both of these can be seen as attempts to restrict the harmful effects of information disclosure that technology transfer would entail.

3.1 Industry-level Support: Chemical Intermediates

Aggregate studies thus support the broad outlines of the theory in section 2. 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 (The Economist, 1998; Chemical Business NewsBase, 1997; Chemical Market Reporter, 1997). A recent overview of trends in pharmaceuticals shows the rapid rise of outsourcing as a percentage of R&D expenditures. Roughly 18% of pharmaceutical R&D funds goes to outsourcing now (The Economist, 1998: Survey p. 16). Some of the most talked-about firms in

the outsourcing industry have acquired production facilities from established pharmaceutical firms, thus getting a helping hand from customers in the creation of an independent outsourcing sector (Gain, 1997)

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"[17] compounds:

> 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. The regulatory climate [favoring purer production with chiral technology], combined with chirals' potential greater efficacy as therapeutics, are driving the rush to patent catalytic agents, processes, and the isolated enantiomer [versions of promising drugs]. . . . Industry analysts agree that process development is shaped by protection of intellectual property and costs.[18]

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[19] or patents on specific catalysts used as intermediates in

---

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

[18] Rose-Maniace, 1997. *See also* Chemical Market Reporter (1997) ("Technology is the differentiator" for makers of fine chemicals, according to an official of ChiroTech, a U.K.-based contract researcher and manufacturer; this firm for example "offers commercial quantities of S-naproxen, via a proprietary . . . bioresolution process.").

[19] *See, e.g.* U.S. Patent 5,684,157, "Process for the preparation of optionally 2-substituted 5-chloroimidazole-4-carbaldehydes," issued Nov. 4, 1997, and assigned to Lonza, Inc.; U.S. Patent 5,446,102, "Olefin metathesis catalysts for degelling polymerization," issued Aug. 29, 1995, assigned to Catalytica Pharmaceuticals, Inc.; U.S. Patent 5,658,796, "Optical resolution of alkyl chroman-2-carboxylates," issued Aug. 19, 1997, assigned to SepraChem, Inc. ("A process for resolving racemic alkyl 1,4-benzodioxan-2-carboxylates useful as intermediates in the synthesis of optically pure pharmaceutical compounds such as (S)-doxazosin is disclosed.")

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.[21]

Most of the companies specializing in chiral compounds, and in fine chemical outsourcing in general, must maintain a close working relationship with their customers.[22] 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 are structured as supply agreements, with the chiral supplier firm's compensation coming when it sells final intermediate product to the customer.[23] There are some common features of the

---

[20] *See, e.g.* U.S. Patent 5,641,726, "Quaternary ammonium carboxylate and borate compositions and preparation thereof," issued Jun. 24, 1997, and assigned to Lonza, Inc. *See generally* SEC Form 10Q, June 30, 1999 ("Catalytica has 37 patents and at least 20 pending patent applications in the United States and approximately 145 patents and patent applications abroad.") (available on SEC EDGAR database at www.sec.gov/edaux/formlynx.htm).

[21] Gain (1997) (quoting Catalytica executive who claims the firm can make drugs for customer faster and cheaper "with the aid of several patented development processes"). *See also* ChiRex, Inc. homepage (http://www.chirex.com) ("Chirex . . . serv[es] the outsourcing needs of the pharmaceutical industry . . . . [and] holds 54 patents and patent applications in the field of chiral chemistry.").

[22] *See, e.g.*, Catalytica, Inc., SEC Form 10-K, October, 1998, available on SEC EDGAR database at www.sec.gov/edaux/formlynx.htm at p. 4:

> Fine chemicals are usually produced to specification in lower volumes using complex manufacturing processes and must satisfy well-defined chemical specifications, which generally results in a closer relationship between the fine chemical producer and the customer. Fine chemicals typically are sold for higher prices than other chemicals. Rapid response to potential customers, reliability of product supply and quality are important competitive factors. . . . A key component of Fine Chemicals' **(Catalytica?)** strategy is to become involved with its customers early in the design of the drug manufacturing process. Fine Chemicals believes that its technology and expertise enables it to develop efficient manufacturing processes at the research and clinical samples stage and successfully scale-up such processes for the manufacture of commercial volumes. These broad capabilities, coupled with its research, pilot and manufacturing facilities, should enable it to develop close relationships with its customers by becoming an integral part of their drug development process and a key preferred supplier of the customer's commercial fine chemical requirements.

See also www.catalytica-inc.com (12/1/00):

> We work closely with our customers, under confidentiality, beginning early in the development of their new catalysts to ensure that reliable, high-quality, cost-effective supplies are available when needed to begin commercial production of the corresponding polymers. Our technology and expertise enable us to demonstrate cost-effective manufacturing processes at the research and development stage, and then efficiently scale these up to manufacture commercial volumes. . . . We develop advanced syntheses of organometallic catalysts for our customers drawing upon an experienced team of Ph.D. organometallic chemists, the extensive proprietary technology of . . . Catalytica Pharmaceuticals, and world-renowned scientific advisors. Process development and scale-up to kilogram quantities is guided by experienced process engineers at our 85,000 square foot R&D center in Mountain View, California . . . .

[23] *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

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, postcontractual, stage, where learning from prior deals is applied to new supply relationships.[24]

There is evidence of the synergies described in our model. Supply agreements often include a license of the *customer's* technology to the supplier firm.[25] 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.[26] By acquiring expertise, these suppliers make themselves more attractive partners for other firms; specialization, backed by property rights, leads to increasing transactional volume.[27]

Operations (UK) Ltd. And Chirex, Ltd., Chirex, Ltd. SEC FORM 8-K, filed Sept. 23, 1997, Exhibit 10.13, available SEC EDGAR database.

[24] *See* www.Lonza.com/custom manufacturing:

> Confidentiality is assured; all work is subject to secrecy agreements. . . . [W]e consider exclusive manufacture our core business, not just a means to fill idle capacity. . . . For more than 20 years, Lonza has been developing and manufacturing fine chemicals for the world's leading life science companies, often on an exclusive basis. Lonza's history as a chemical company goes back 100 years. Today, we are at the forefront for exclusive synthesis of fine chemicals and the world number one for custom-made biochemicals – a position we maintain through our offices and plants in fifteen countries around the industrialized world. Lonza has the people, facilities and financial muscle to see projects through . . . In the age of the time-to-market imperative, we have honed our organization to give the responsiveness that makes the difference. Over the years we have developed a close and long-lasting relationship with a number of leading life science companies. Would you like to join the family?

[25] *See* Supply Agreement between Chirex, Ltd. And Cell Therapeutics, Inc. § 12.3, at p. 15.

[26] *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].

The Agreement does not define what it would mean for an improvement to be "specific" to Glaxo's products, but it is very likely that Chirex learns much in the course of each supply relationship that it can use in its others. It is Chirex's ownership of its own production technology – the patents to its chiral intermediates and ways to produce them – that encourages Chirex to invest in the Glaxo-specific know-how required to adapt Chirex technology to Glaxo's products.

[27] *See, e.g.*, www.catalytica-inc.com (12/1/00):

> Since the acquisition of the Greenville Facility from Glaxo Wellcome in 1997, Catalytica has entered into over 40 new agreements for the development and manufacture of products for various pharmaceutical and

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.[28] Rose-Maniace (1996), for instance, describes custom manufacturing firm Albermarle, Inc., which "has patents on S^+-ibuprofen production, which it makes in small quantities for a [single] customer in Europe." There is thus 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. And it is clear that in the long term, these investments will be firm-specific, and protected, if at all, as trade secrets (Rose-Mariace, 1996).[29]

There is, as one would expect, significant firm entry in this specialized niche as a consequence.[30] Several established firms have entered this market, by spinning off contract manufacturing operations into independent companies (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

---

biotech companies. In anticipation of additional business, it has expanded its chemical manufacturing facility and is currently expanding its sterile facility. It is the largest independent, fully integrated drug development and manufacturing supplier in the world. Catalytica, Inc., through its subsidiaries, applies its proprietary technologies to improve manufacturing and solve . . . problems.

See also Catalytica, Inc., SEC Form 10Q, filed June 30, 1999 (avail. SEC EDGAR database):

Research and development expenses increased 23% and 37%, respectively, for the three and six months ended June 30, 1999, as compared to R&D expenses in the same periods in 1998. This increase in R&D expenses directly corresponds to an increase in R&D income attributable to increased staffing and associated R&D expenses at the Greenville Facility which is expanding the R&D services it provides with respect to both chemical process and formulation development.

[28] *See, e.g.*, Chirex, Inc., 1998 Form 10-K405, *supra*, at 8 (emphasis added):

The Company's current competitors include Alusuisse-Lonza Holdings AG, DSM Andeno B.V. and Laporte PLC. *In addition, the Company competes with major pharmaceutical manufacturers (including a number of the Company's customers) who develop their own process technologies and manufacture fine chemicals and pharmaceutical intermediates in-house.*

[29] Rose-Mariace (1996) (quoting industry consultant): "In the short term, a great deal of process work and patenting is still being done. In the longer term, optimization of the processes will be protected as trade secrets."

[30] *Cf.* Manufacturing Chemist (1997: 11) ("The trend to outsourcing means that small niche companies are springing up to provide contract synthesis and clinical trials . . . .").

> 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 Sepracor spinoff, was created to produce and commercialize intermediate inputs for the drug industry. It operates under licenses to Sepracor's proprietary technology, which includes 46 US patents for the synthesis of chiral intermediates.[31]

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).

3.2 Case Study: Alkermes-Genentech Supply Agreement

To give some real-world context, we will consider in some depth 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 is one of a number of firms working on advanced drug delivery techniques. Some are well known, such as the transdermal patches now common for delivery of nicotine and nitroglycerin. Others are more exotic. Alkermes, for instance, has developed a procedure for coating an active ingredient in very thin polymeric capsules. The capsules are made of material

[31] Lepree (1995). Lepree (1995) also states: "SepraChem presently produces intermediates and actives for Sepracor and other drug companies, using its [proprietary] ChiRedox platform of chiral synthesis and separation."

that breaks down over time in the human body. Unlike traditional encapsulation (e.g., the "thousands of tiny time capsules" of "Contac" cold medicine fame), Alkermes' 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. It is certainly no barrier that novel delivery vehicles require sophisticated manufacturing. 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, there is something about the capabilities of Alkermes that makes it attractive for Genentech to buy from Alkermes.

Genentech is not alone. The Alkermes business model is to develop microencapsulated versions of highly successful drugs.[32] This it does in close collaboration with the large drug firms that own the rights to the drugs: it has deals with Schering-Plough, Johnson and Johnson, and of course Genentech, among others. Drug firms enter into these deals to access Alkermes' proprietary delivery technology, which makes the drugs easier to take, and in some cases opens up new submarkets not available using conventional delivery techniques.[33]

---

[32] *See, e.g.*, Tracy, et al., U.S. Patent 5,711,968, issued Jan. 27, 1998, "Composition and method for the controlled release of metal cation-stabilized interferon"; Lewis, et al., U.S. Patent 5,733,566, issued Mar. 31, 1998, "Controlled release of antiparasitic agents in animals" (according to specification, works with Merck's avermectin product). *See also* patents cited Note 40, *infra*.

[33] *See, e.g.*, Mary Welch, "Extended Formulation Strong in Phase III Study, Genentech, Alkermes Report," BioWorld, Oct. 23, 1998,

> "Both companies probably will start Nutropin Depot trials on adults at some point," [Richard] Pops [, CEO of Alkermes] said. "With adults, it's not a matter of trying to increase height, but there are some other manifestations of growth hormone deficiency ," he said. "A lot of adults don't take growth hormones because they don't want to deal with daily shots."

The basic structure of the Genentech-Alkermes deal follows the logic of the TCE literature.[34] There are two stages to the transaction: (1) Alkermes adapts its microencapsulation drug delivery technology to Genentech's successful therapeutic product, a genetically engineered form of the naturally-occurring protein called Human Growth Hormone (HGH); and (2) Alkermes manufactures the product for Genentech and sells it at a pre-agreed price, with Genentech then marketing and distributing it.[35] 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. 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.[36] As would be expected, Alkermes grants a license to Genentech for the use of this knowhow during the course of the agreement, but such information is rarely set down in "codified" form and hence is difficult to monitor or transfer. This aspect of the License Agreement does not survive termination, which means that Alkermes is free to use and adapt the knowhow it develops whether or not it sells product to Genentech. The agreement thus contemplates the creation of information that might well be useful to Alkermes in subsequent supply relationships, and makes no attempt to prevent Alkermes from using that information in the future – good evidence for the synergies discussed in our model in section 2.

---

[34] 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").

[35] 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).

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' 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 commercial grade product that meets 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 pediatric [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].[37]

---

[36] The Agreement provides for an up-front prepaid royalty and a small loan from Genentech, but does not characterize this as payment for development of the knowhow. It would be very hard to verify that particular funds were used to developed knowhow, or to evaluate the quality of the knowhow, in any event.

[37] 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 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' 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' SEC Form 10K, filed June 29, 1998 (avail. 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].

So what protection does Alkermes have? One important one is ownership of the assets that enable production of the microencapsulated drug that Genentech wants. While 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' 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. As the theory developed here predicts, Alkermes is quite "patent intensive".[38] Alkermes currently has 43 patents covering (1) its microencapsulation process;[39] (2) novel polymers and preparations that make up the coatings;[40] and (3) microencapsulated formulations of the drugs it delivers under its collaboration agreements. These patents support the firm's strategy of developing general-purpose delivery technologies that can be applied to many products.[41] They 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.[42] Alkermes's patents over the design and

---

[38] As of 2000, Alkermes had 43 U.S. 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.

[39] *See, e.g.*, Rickey, et al., U.S. Patent 6,110,503, "Preparation of biodegradable, biocompatible microparticles containing a biologically active agent," issued Aug. 29, 2000 (assigned to Alkermes); Rickey, et al., U.S. Patent 5,916,598, "Preparation of biodegradable, biocompatible microparticles containing a biologically active agent," issued June 29, 1999 (assigned to Alkermes); Rickey, et al., U.S. Patent 5,792,477, "Preparation of extended shelf-life biodegradable, biocompatible microparticles containing a biologically active agent," issued Aug. 11, 1998 (assigned to Alkermes).

[40] *See, e.g.*, Herbert, et al., U.S. Patent 6,153,129, "Production Scale Method of Forming Microparticles," issued Nov. 28, 2000 (assigned to Alkermes).

[41] Alkermes SEC 10K-405 filing, June 29, 2000 (emphasis added) (avail. www.sec.gov/Archives/edgar/data/874663):

> Our current focus is on the development of broadly applicable drug delivery technologies addressing several important drug delivery opportunities, including injectable sustained release of proteins, peptides and small molecule pharmaceutical compounds, the pulmonary delivery of both small molecules and proteins and peptides, drug delivery to the brain across the blood-brain barrier and oral drug delivery systems. We are applying delivery technologies to develop programs for our collaborators and for our own account. . . . *Our experience with the application of ProLease [delivery technology] to a wide range of proteins and peptides* has shown that high incorporation efficiencies and high drug loads can be achieved.

[42] License Agreement, §§ 1.3 (Definition of "Alkermes Patents," which includes after-acquired patents relating to protein microencapsulation); 2.1(A) (Grant of License Right to Genentech); and 9 (Termination: grant of license does not survive termination).

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

The model in section 2 is predicated on the idea that each supply contract provides opportunities for Alkermes to recognize and develop new applications of its technology because it is an independent firm. Alkermes has now adapted its microencapsulation technology to a number of highly profitable pharmaceutical products sold by other firms. In fact, it has now obtained four patents on the microencapsulated form of Genentech's HGH.[43] Alkermes has several patents on microencapsulated versions of other best-selling therapeutic products in the biotechnology industry, including Schering-Plough's Alpha Interferon.[44]

The three HGH-specific patents were applied for after the commencement of the Genentech relationship. Clearly, Alkermes is deriving significant synergies from its interactions with buyers such as Genentech. (A patent requires novel, useful, and nonobvious invention; hence the development of newly patentable aspects of Alkermes' previously patented generic

---

[43] *See* Alkermes Press Release, September 26, 1996, available at www.alkermes.com.

> "Alkermes is building an extensive portfolio of patents and patent applications relating to its ProLease and Medisorb® drug delivery systems," said Richard F. Pops, Chief Executive Officer of Alkermes. "This [HGH] patent is an important component of the intellectual property developed in our ProLease human growth hormone program."

The collaboration agreement explicitly permits Alkermes to retain ownership of patents it develops on its own, even those relating to Genentech's technology. While *jointly developed* inventions are jointly owned under the agreement, these are limited to cases where one or more of the inventors listed on the patent work for each of the firms. The Alkermes-Genentech Agreement (at § 10.1) states:

> The Parties recognize that either Party may independently and separately make inventions during the course of this Agreement relating to human growth hormone, delivery systems for human growth hormone, PLGA encapsulation of proteins or otherwise related to the scope of this Agreement . . . .

[44] *See, e.g.*, Johnson et al., U.S. Patent 6,051,259, "Composition for Sustained Release of Human Growth Hormone," issued April 18, 2000 (assigned to Alkermes, Inc.); Johnson et al., U.S. Patent 5,891,478, "Composition for Sustained Release of Human Growth Hormone," issued April 6, 1999, (assigned to Alkermes); Johnson, et al., U.S. Patent "5,667,808, "Composition for Sustained Release of Human Growth Hormone," issued September 16, 1997 (assigned to Alkermes, Inc.); Johnson, et al., U.S. Patent 5,654,010, "Composition for Sustained Release of Human Growth Hormone," issued Aug. 5, 1997 (assigned to Alkermes); Johnson, et al., 5,674,534, "Composition for Sustained Release of Non-Aggregated Erythropoietin," developed in conjunction with a collaboration with Johnson & Johnson, Inc. (see Licensing Agreement, Exhibit 10.2, Alkermes SEC Form 8-K, Nov. 14, 1996, available www.sec.gov/edaux/formlynx.htm. Similar patents have issued for microencapsulated Alpha interferon, which grew out of a collaboration with Schering-Plough Corporation. *See* Alkermes, Inc., SEC Form 10-K, filed March 31, 1998, available at www.sec.gov/edaux/formlynx.htm.

technology implies the creation of synergistic information.)[45] Evidence from Alkermes' supply agreements supports the thesis that Alkermes always "takes back" its technology (and, by implication, whatever know-how it has acquired) when a collaboration is terminated, e.g., because of unsatisfactory progress.[46] According to Alkermes' CEO, "We have multiple collaborations in place for our sustained release drug delivery systems . . . [and] [w]hile we hope that each will lead to a marketed product, we know that attrition is inevitable. *Every program contributes to the overall development of our technologies . . . .*"[47] Alkermes is clearly learning something on each project, adding to the firm's knowledge base. The Alkermes-Genentech Agreement supports this objective, by (1) allowing Alkermes to take title to its own HGH-related inventions, (2) even where those inventions come to fruition in the postcontractual phase (stage 3 of our model): the provision permitting Alkermes ownership of patents derived from the relationship states that it "shall survive the termination or expiration of this Agreement."

To summarize: Alkermes has obtained a steady stream of patents on general aspects of microencapsulation. Its ownership of numerous patents on "generic" aspects of its

---

[45] Internal evidence from the patents themselves supports this view. Alkermes' U.S. Patent to Johnson et al., U.S. 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.

[46] *See, e.g.*, Press Release, April 22, 2000, "Update on Collaborations: Undisclosed Compound," avail. 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 termination of the collaboration, Alkermes regains rights licensed to PRI for the development and marketing of sustained release formulations of this class of compounds.* Alkermes first announced the collaboration in December 1996. The objective of the collaboration was to apply the ProLease drug delivery system to a . . . proprietary compound being developed for the treatment of hormone-mediated disorders. A ProLease formulation of the proprietary compound completed a human clinical trial in 1997 and demonstrated sustained release for the intended duration of time. [The partner] has discontinued further development of this compound.

Note (1) the recapture of rights, and (2) the fact that Alkermes acquired additional expertise, given that its part of the project was accomplished successfully.

[47] Press Release, Nov. 16, 1998, "Alkermes Updates Status of Pro-Lease Collaborations," heading "Intron A," announcing termination of Alkermes-Johnson and Johnson collaboration to develop sustained release formulation of Johnson and Johnson's Intron-A product, avail. www.alkermes.com/news (emphasis added).

microencapsulation technology is consistent with the role patents play in the model of section 2 of this Article. In addition, evidence from Alkermes' various supply relationships shows that numerous patentable inventions have resulted from the adaptation of the generic technology to particular customer needs. This shows that Alkermes has expended considerable effort in implementing these supply agreements. The overall impression is that the Alkermes-Genentech supply agreement shows a good fit between the structure of biotechnology agreements and many features of our model.

3.3 Post-Contractual Period: Evidence of Synergies and Rent Dissipation

Neither specialty chemical supply deals, nor the Alkermes-Genentech agreement, provide any evidence so far of post-contractual rent dissipation. So we must turn to evidence drawn from other supply relationships. A quick review of several recent cases drawn from Merges (2000a) will suffice to show that rent dissipation is a plausible follow-on to an information-intensive supply relationship. We make no claims of completeness or representativeness in this presentation, however.

Recall from section 2 that dissipation may result when MU and RU compete in the exploitation of the new knowledge revealed in the course of the RU-MU supply relationship. With this in mind, consider several recent cases drawn from reports of litigated IPR cases. The first, *Simula, Inc. v. Autoliv, Inc.*,[48] 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 Autliv in connection with a deal to supply BMW with head restraint airbags. Autoliv then approached Mercedes, which asked Autoliv to design and

[48] 175 F.3d 716 (9th Cir. 1999).

supply a modified version of the Simula design as a head restraint system in Merecedes cars. Autliv 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 Autloliv-Mercedes design, and brought suit to prevent being "squeezed out." Extensive litigation followed, with Simula fighting in mutiple legal forums to stay an active player in the market for its specialty air bags.[49]

Next, *Beech Aircraft Corp. v. EDO Corp.*,[50] involved a design firm (EDO) that had contracted to develop a wing structure for a new airplane to be manufactured by Beech. After the design work had been completed, Beech terminated the supply agreement. The two parties filed separate, conflicting patent applications on the wing structure, which the courts had to sort out in the course of a lengthy and complex litigation.

Finally, consider *Neway Anchorlok, Int'l v. Longwood Industries*.[51] In this case, a supplier's proprietary manufacturing information was disclosed to a customer firm in the business of making diaphragms for brakes used on commercial vehicles, e.g., large trucks. The customer was in fact the inventor of a widely used brake design. In subsequent litigation, the supplier attempted to prevent the brake manufacturer from making its own brakes using the supplier's proprietary information.[52]

4.0 Conclusion

[49] Telephone interview with John Alan Doran, attorney for Simula, Inc., 12/4/00.
[50] 990 F.2d 1237 (Fed. Cir. 1993).
[51] 107 F.Supp.2d 810 (W.D. Mich. 1999).
[52] In this case, the supplier's information was transferred to the manufacturing firm by an ex-employee, who was subsequently enjoined from further disclosure of the supplier's trade secrets. The case therefore illustrates the effects of dissipation when synergistic rents are created in the absence of a valid supply agreement. The point remains, however, that the two parties to the case ended up competing over markets for products and information that resulted from synergistic intermixture of their respective information – the manufacturer's proprietary brake design, and the supplier's manufacturing-related trade secrets.

We have modeled the effects of property rights on the "make or buy" decision concerning information-intensive inputs. We feature a tradeoff: between integration, which avoids rent dissipation; and a freestanding input supply firm with property rights, which can encourage generation of synergistic information, in addition to the conventional benefits of specialization. This explains the increasingly common phenomenon of independent suppliers of information-intensive inputs. We also show that, perhaps counterintuitively, the advantages of specialization increase when anticipated synergies are large. In other words, when the future spillovers relate to a larger market, specialization is more efficient. The intuition is that an increase in the spillover rents increases the joint payoff to increasing the probability of spillovers. The probability increases with RU's efforts, which are higher under specialization than under integration.

We do not mean to argue that spillovers and synergies are always the dominant motivations for specialization. In particular, two additional issues, not directly accounted for in our model, deserve mention: (1) economies of scale and reduced duplication from specialization; and (2) high spillover/low appropriability environments, which may provide an independent rationale for specialized firms.

Conventionally, an independent RU has multiple customers for its input. This allows the usual "extent of the market" benefits; for example, there may be economies of scale in producing the input. In addition, RU learns something from each customer. This information is aggregated in the hands of RU, in a way it would not be if each producer used an integrated supplier. RU is thus in a position to disseminate (at least some) "best practice" information, in a manner quite familiar from the literature on specialized engineering firms in the chemical industry (Arora and Gambardella, 1998; Freeman, 1968). Finally, an independent RU may be more efficient in disseminating new applications because a single source lowers transaction costs. Other potential

users of Input Q need not approach MU, and all other producers, for the latest information relating to Input Q. Relatedly, RU is likely to be a central source for property rights relating to Input Q and its applications – either as owner, or in a "clearinghouse" role.[53] There may be transactional economies of scale, in other words.

Another potential advantage of specialization relates to a specialized firm's role in disseminating information. Such firms may facilitate inter-firm information flows, which in some cases may be efficient for all involved. The loss from leakage of MU information may be offset by the gain from RU's sharing of other firm's information. This is similar to "informal know-how sharing" among process engineers in the steel industry (von Hippel 1987; Schrader, 1991; Harhoff, Henkel and von Hippel, 2000). It is also related to motives for firm participation in "open source" software development (Lerner and Tirole, 1999; von Hippel, 2000), and to the sharing of information among research scientists (Merges, 1996a).[54] To be sure, firms do not always need specialized intermediaries to facilitate spillovers. But specialized firms may mediate information flows in ways that make it acceptable to industry members, for example by selectively sharing information or by disseminating it after some time lag. Trust and reputation may play a role as well. Though speculative, these potential benefits of specialization must be acknowledged. A tolerance on the part of MU for high spillovers is not inconsistent with the story of our model, but it would reduce the deleterious effects from leakage, and might suggest a countervailing consideration in the firms' preferences regarding property right strength, or at least enforcement.

[53] This may reduce transaction costs related to fragmented ownership (i.e., the "anticommons" problem; see Heller, 1998).

[54] The general phenomenon of high inter-firm spillovers leading to more firm-level R&D has been studied empirically by Levin (1988) and modeled by Levin and Reiss (1988: 544) and Cohen and Levinthal (1989).

While the theory presented here is not a comprehensive theory of specialization, it does extend our understanding of the incentive effects of IPRs. Stronger patents in our model lead to more firm specialization. Independent research-intensive suppliers are more viable at the margin when stronger patents are available. Patents thus 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 has obvious implications for firm strategy. It also should affect our views of the economic consequences of strengthening IPRs. The conventional story of stronger property rights and greater incentives to innovate remains intact. But the mechanism we introduce goes beyond the conventional correlation between property right strength and expected profit. 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.

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. Straightforward extensions of our model also shed light on two issues of recent interest: (1) use of options to buy R&D units as a way to resolve sequential investment problems under incomplete contractibility; and (2) spinoffs from parent firms.

Our model demonstrates a plausible connection between property rights, firm boundaries, and even industry structure. And by drawing on two heretofore disparate strands of analysis – the economics of property rights and transaction cost economics – we also demonstrate some interesting interaction effects between two foundational legal categories, property and contract. For example, one implication (though not a direct result) of our model is that property rights can serve as "hard" constraints on the behavior of a contracting party – that is, constraints that are robust to (at least some) efforts to renegotiate contracts, and even to post-contract termination

behavior. This breathes life into the “residual rights” concept of property, and further illuminates ways in which property rights specifications can open up new contracting horizons.

References

Aghion, Phillip, and Jean Tirole. 1994. "On the Management of Innovation,"109 Q.J. Econ. 1185-1207.

Alston, Lee J., Thrainn Eggertson and Douglass C. North. 1996. Toward an Understanding of Property Rights, Editors' Introduction to Gary Libecap, Economic Variables and the Development of the Law: The Case of Western Mineral Rights, in Empirical Studies in Institutional Change (Lee J. Alston, Thrainn Eggertson and Douglass C. North, eds.), 31-33.

Alston, Lee J., Gary D. Libecap and Robert Schneider. 1996. The Determinants and Impact of Property Rights: Land Titles on The Brazilian Frontier, 12 J.L. Econ. & Org. 25.

Alston, Lee J., Gary D. Libecap and Robert Schneider. 1994. Property Rights and the Preconditions for Markets: The Case of the Amazon Frontier, 151 J. Institutional and Theoretical Econ. 89-107.

American Petroleum Institute, EnCompass, 1999. BP Amoco Transfers Topnir Technology to Eutech. API EnCompass: News, Aug. 4, 1999 (avail. Westlaw 1999 WL 23817765).

Anand, Bharat N. and Tarun Khanna. 1996. "Intellectual Property Rights and Contract Structure." Mimeo, Harvard Business School, Working Paper 97-016.

Arora, Ashish, and Alfonso 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 and Sons, New York.

Arora, Ashish. 1996. Contracting for Tacit Knowledge: The Provision of Technical Services in Technology Licensing Contracts, 50 J Development Econ 233-256.

Arora, Ashish. 1995b. Licensing Tacit Knowledge: Intellectual Property Rights and the Market for Know-how, 4 Econ. Innovation & New Tech. 41-59.

Baker, George, Robert Gibbons and Kevin J. Murphy, "Relational Contracts and the Theory of the Firm," mimeo, Dec. 29, 1997.

Ball, Philip. 1994. Designing the Molecular World: Chemistry at the Frontier (Princeton, N.J.: Princeton University Press).

Barzel, Yoram. 1989. Economic Analysis of Property Rights (Cambridge, England: Cambridge University Press).

Besley, Timothy. 1995. Property Rights and Investment Incentives: Theory and Evidence from Ghana. 103 Journal of Political Economy 903-937.

Chemical Market Reporter. 1997. "ChiRex Sale of APAP Business a Move to Focus on Contracting," June 2, 1997.

Chemical Market Reporter. 1996. "Outsourcing in Europe Adapts," August 5, 1996.

Crow, Michael M., Annetine C. Gelijns, Richard N. Nelson and Bhaven N. Sampat. 1998. Recent Changes in University-Industry Research Interactions: A Preliminary Analysis of Causes and Effects, undated Working Paper.

Curtis, George Ticknor. 1849 Treatise on the Law of Patents for Useful Inventions (Boston: Little, Brown).

D'Aveni, Richard A., and David J. Ravenscraft. 1994. "Economies of Integration Versus Bureaucracy Costs: Does Vertical Integration Improve Performance?" 37 Acad. Mgt. J. 1167.

De Meza, David, and Ben Lockwood. 1998. "Does Asset Ownership Always Motivate Managers? Outside Options and the Property Rights Theory of the Firm," 113 Q. J. Econ. 361-387.

Demsetz, Harold. 1967. “Toward a Theory of Property Rights.” 57 Am. Econ. Rev. 347-59, reprinted in 1 Ownership, Control and the Firm (Oxford: Blackwell), 31-46.
The Economist. 1998. “Beyond the Behemoths,” in Pharmaceutical Industry Survey, vol. 346, Feb. 21, 1998, Survey p. 16.
Eggertson, Thráinn. 1990. Economic Behavior and Institutions. Cambridge: Cambridge University Press.
Eisenberg, Rebecca S. “Public Research and Private Development: Patents and Technology Transfer in Government-sponsored Research,” 82 Va. L. Rev. 1663-1727.
Ellickson, Robert. 1993. “Property in Land.” 102 Yale L. J. 1315-1400.
Gain, Bruce. 1997. “Custom Manufacturing Takes Off.” Chemical Week, May 14, 1997, p. S10.
Gans, Joshua S., David H. Hsu and Scott Stern. 2000. “When Does Startup Innovation Spur the Gale of Creative Destruction?” NBER Working paper 7851, August 2000.
Gemser, Gerda and Nachoem M. Wijnberg. 1995. “Horizontal Networks, Appropriability Conditions and Industry Life Cycles,” 2 J. Indus. Studies 129-147.
Gompers, Paul, and Josh Lerner. 1999. The Venture Capital Cycle. Cambridge: MIT Press.
Grossman, Gene M. and Elhanan Helpman. 1999. “Incomplete Contracts and Industrial Organization” (Nat’l Bureau of Econ. Res. Working Paper 7303, August 1999).
Grossman, Sanford J. and Oliver D. Hart, 1986. “The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration,” 94 J. Pol. Econ. 691-719.
Hart, Oliver. 1989. “An Economist's Perspective on the Theory of the Firm,” 89 Colum. L. Rev. 1757-1774.
_____. 1995. Firms, Contracts, and Financial Structure. Oxford: Oxford University Press.
_____ and John Moore, 1990. “Property Rights and the Nature of the Firm,” 98 J. Pol. Econ. 1119-58.
Heller, Michael A. 1998. “The Tragedy of the Anticommons: Property in the Transition from Marx to Markets,” 111 Harv. L. Rev. 621-688.
Hellmann, Thomas, and Manju Puri. 1999. “The Interaction between Product Market and Financing Strategy: The Role of Venture Capital” Working paper, Dec. 1999, avail www.ssrn.com.
Journal of Proprietary Rights (1993a). "Japan IP Update." 5:31.
Knez, Mark, and Duncan Simester. 2000. “Direct and Indirect Bargaining Costs and the Scope of the Firm.” Working Paper, avail. www.ssrn.com.
Kortum, Samuel and Josh Lerner. 1997. AStronger Protection or Technological Revolution: What is Behind the Recent Surge in Patenting?,@ Harvard Business School Working Paper 98-012.
Johnson, Shane A. and Mark B. Houston. 2000. “A Reexamination of the Motives and Gains in Joint Ventures,” J. Fin. & Quant. Anal. 25.
Lamoreaux, Naomi R., and Kenneth L. Sokoloff. 1996. “Long-term Change in the Organization of Inventive Activity.” 93 Proc. Nat’l Acad. Sci. 12686-12692.
Lepree, Joy. 1995. “Fine Chemical Spinoffs Set,” Chemical Marketing Reporter, January 30, 1995.
Lerner, Josh, and Robert P. Merges. 1998. “The Control of Technology Alliances: An Empirical Analysis of the Biotechnology Industry.” 46 J. Ind. Econ. 125-156.
Libecap, Gary D. 1978. The Evolution of Private Mineral Rights. New York: Arno Press.
Libecap, Gary D. 1989. Contracting for Property Rights. Cambridge: Cambridge University Press.

Libecap, Gary D. 1993. Entrepreneurship, Property Rights and Economic Development, in Advances in the Study of Entrepreneurship, Innovation and Economic Growth, 6 pp. 67-83.

_____ and Steven N. Wiggins. 1985. "The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Unitization," 93 J. Pol. Econ. 690-714.

Manufacturing Chemist, 1997. "'Build and Go' Formula for New Structures," Dec. 1997, p. 11.

Merges, Robert P. 1988. Economic Perspectives on Innovation: Commercial Success and Patent Standards, 76 California Law Review 803-876.

Merges, Robert P. 1991. "The Public Interest and Private Patent Bills," Hearings on Patent Extensions (Private Patent Bills), Committee on the Judiciary, U.S. Senate, August 1, 1991.

Merges, Robert P. 1994. "Of Property Rules, Coase, and Intellectual Property, Symposium: Toward a Third Paradigm in Intellectual Property," 94 Colum. L. Rev. 2655-2673 (1994).

Merges, Robert P. 1995. "Intellectual Property and the Costs of Commercial Exchange: A Review Essay," 93 Mich. L. Rev. 1570.

Merges, Robert P. 1996. "A Comparative Look at Intellectual Property Rights in the Software Industry," in The International Computer Software Industry: A Comparative Study of Industry Evolution and Structure (Oxford Univ. Press) (David Mowery, ed.), 272-303.

Merges, Robert P. 1997a. "Contracting Into Liability Rules: Intellectual Property Transactions and Collective Rights Organizations", 84 California L. Rev 1293-1392.

Merges, Robert P. 1997b. "The End of Friction? Property Rights and Contract in the Newtonian World of On-Line Commerce," 12 Berkeley Tech. L.J. 115.

Merges, Robert P. 1997. Patent Law and Policy (2d ed.). Charlottesville, VA: Lexis Law Pub.

Merges, Robert P. 2000a. "Property Rights as Contractual Safeguards." Working paper, December, 2000.

Moore, Ann. 1996. "When Outsourcing Makes Most Cents. Business Chicago," April 01, 1996, p. 21.

Mowery, David M. and Nathan Rosenberg. 1989. Technology and the Pursuit of Economic Growth (Cambridge: Cambridge university Press).

Noldeke, Georg and Klaus M. Schmidt. "Sequential Investments and Options to Own." Working Paper, University of Basel, March, 1998.

North, Douglass C. 1990. Institutions, Institutional Change and Economic Performance. Cambridge: Cambridge University Press.

Oxley, Joanne E. 1999. "Institutional Environment and the Mechanisms of Governance: The Impact of Intellectual Property Protection on the Structure of Inter-firm Alliances." 38 Journal of Economic Behavior & Organization 283-309.

Pooley, James. 1999. "Litigation and Enforcement of Trade Secrets." Practicing Law Institute Pub. No. 574 PLI/Pat 619.

Poppo, Laura, and Todd Zenger. 2000. "Substitutes or Complements? Exploring the Relationship between Formal Contracts and Relational Governance," Working Paper, April 27, 2000, avail. http://papers.ssrn.com/paper.taf?abstract_id=223518.

Quinn, James Brian. 1999. "Strategic Outsourcing: Leveraging Knowledge Capabilities." 40 Slaon Mgt. Rev. 9-21.

Reynolds, Glenn H. and Robert P. Merges. 1997. Outer Space: Problems of Law and Policy. Boulder, CO: Westview Press (2d edition).

Rose, Robert L. 1997. "Driving Ahead; UAW Turns up Heat on Johnson Controls as Company Perfects Auto Supply Business" Pittsburgh Post-Gazette, February 5, 1997, p C9.
Rose-Maniace. 1996. "The Rush to Patent (Special Report: Custom Manufacturing '96)." Chem. Marketing Reporter, Jan. 29, 1996, p. SR 6.
Sandburg, Brenda. 1998. "When Strategic Alliance Leads to the Courthouse," IP Magazine ([San Francisco] Recorder), November, 1998, at p. 1.
Stevenson, Richard. 1997. If You've Got It, License It. Chembytes, 1997 (avail. http://www.chemsoc.org/chembytes/ezine/1997/urethane.htm).
Schwartz, Alan. 1979. "The Case for Specific Performance," 89 Yale L.J. 271.
Shan, Weijan, and Jaeyong Song. 1997. "Foreign direct investment and the sourcing of technological advantage: Evidence from the biotechnology industry," 28 Journal of International Business Studies 267-284.
Stites, Janet. 1998. "Prospectus: For Start-up Companies Looking for Corporate Investors, it Pays to Know that Philosophies Differ from East to West," N.Y. Times, Mon. Nov. 9, p. C4.
Tadeschi, Bob. 2000. E-Commerce Report: A Nobel Prize-winning Idea, Conceived in the 1930s, is a Guide for Net Business, N.Y. Times, Mon Oct 2, 2000, p. C12, cols 1-5.
Takaishi, M. 1986. "The Perspectives from Japan on Software Protection." Software Law Journal 1:187.
Teece, David. 1986. "Profiting from Technological Innovation: Implications for Licensing, Integration and Public Policy" 15 Research Policy 285-307.
Telser, Lester G. 1980. "A Theory of Self-Enforcing Agreements." 53 Journal of Business 27-44.
Von Hippel, Eric. 1988. The Sources of Innovation. Cambridge, Mass.: MIT Press.
Williamson, Oliver. 1983. "Credible Commitments: Using Hostages to Support Exchange." 73 Am. Econ. Rev. 519-540.
_____. 1985. The Economic Institutions of Capitalism. New York: Free Press.
_____. 1996. The Mechanisms of Governance. New York: Oxford University Press.
Zeckhauser, Richard. 1996. "The Challenge of Contracting for Technological Information," 93 Proc. Natl. Acad. Sci. 12743-12748.

Appendix: Buyouts and Breakoffs

Specialization

If the MU can buy the RU after the new application is realized, then there is no rent dissipation under specialization. We assume that the buyout payment, T_3 , is specified ex ante. Thus, in stage 3, if leakages or synergies take place, MU offers to buy out the RU by paying T_3. Assuming that the offer is accepted (i.e., $\Pi - \Pi_M \geq T_3 \geq \Pi_R$). At stage 1, X and Z are chosen as follow

$$X_s = \arg\max \tfrac{1}{2}(V(X) - L(X)) - C(X) + P(X, Z)(T_3)$$
$$Z_s = \arg\max \tfrac{1}{2}(V(X) + L(X)) + P(X, Z)(\Theta - T_3 - W) + W \qquad \text{(A1)}$$

Under leakages, $\Pi = W$ so that $(\Pi - W - T_3)$ is strictly negative. Accordingly MU chooses $Z_s = Z^{min}$, as was the case without a buyout possibility. Further $T_3 \geq \Pi_R$, so that RU chooses at least as high a level of effort as without the buyout. Consequently the joint surplus is strictly greater than that without the possibility of a buyout.

Under synergies, $(\Pi - W - T_3) > (\Pi - \Pi_M - T_3) > 0$. Therefore MU chooses $Z_s = Z^{max}$, as was the case without a buyout possibility. Since $T_3 \geq \Pi_R$, so that RU chooses at least as high a level of effort as without the buyout. Consequently the joint surplus is strictly greater than that without the possibility of a buyout.

Vertical Integration

If RU has the option of spinning off, MU would prefer to "buy" this option in the event that it is worth exercising this option. If T_3 is the price MU pays for this option, then we must have that $\Pi - \Pi_M \geq T_3 \geq \Pi_R$. However, since MU owns the intellectual property relating to the input technology, RU cannot force it to "invent around" at stage 2. Thus at stage 1 the X and Z are chosen as given below

$$X_I = \arg\max P(X, Z)(T_3) - C(X, Z)$$
$$Z_I = \arg\max V(X) + P(X, Z)(\Theta - T_3 - W) + W \qquad \text{(A2)}$$

The possibility of getting rents from the new application provides some incentives to the RU for customization, although these incentives need not be sufficient to induce an effort greater than the baseline effort. It is also easy to see that under leakages (synergies), MU chooses the minimum (maximum) level of openness. Since the levels of Z are the same under both structures, then as long as the buyout payment under specialization is at least as great as the buyout payment with spinoffs, X is strictly lower under integration (i.e., $X_I < X_s$), and thus, the joint surplus is higher under specialization than under integration.

To see that the buyout payment under specialization is at least as great as the buyout payment with spinoffs, note that if the payment is decided through negotiation at stage 3, then we have $T_3 = \tfrac{1}{2}(\Pi + \Pi_R - \Pi_M)$, so that it is the same under both integration and specialization. If instead the parties can contractually agree on the payment ex ante, then it follows that they would use the highest possible payment in order to provide RU with the greatest possible incentive. However, if the payment is greater than $\Pi - \Pi_M$, MU will be tempted to renege. (Alternatively, if MU has the option to buy, as in Noldeke and Schmidt (1998), then if the buyout price is greater than $\Pi - \Pi_M$, it will not exercise the option.) Therefore, the payment will be set at $\Pi - \Pi_M$ under both integration and specialization. Proposition A1 formalizes this.

Proposition A1 *When buyouts and spinouts are allowed, specialization results in (weakly) greater joint surplus. If intellectual property rights are strong enough to induce MU to make second period payments, then specialization provides superior incentives for customization and yields strictly grater joint surplus than integration.* (ii) *Buyouts happen with probability P(X,Z), whereas spinoffs do not take place in equilibrium.* (iii) *Ceteris Paribus, joint surplus is higher when buyouts are allowed than when they are not.*