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LICENSING TACIT KNOWLEDGE: INTELLECTUAL PROPERTY RIGHTS AND THE MARKET FOR KNOW-HOW

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Technology transfer involves more than just the permission to use knowledge covered by patents; the transfer of know-how is critical to the successful utilization of the transferred technology. However, know-how is typically difficult to codify, costly to transfer, and hence, difficult to contract upon. Using a principal-agent model I show that simple arms length contracts can accomplish the transfer know-how. The key to the success of arms length contracts is the complementarity between know-how and patents. The model explains why patents and know-how are bundled together in licensing contracts. It shows why licensing has limitations as a strategy for appropriating rents from innovation. The paper points to the key role that patent scope plays in determining the efficiency of know-how transfer and shows that broader patents can improve the efficiency of technology transfer, even when important components of the technology (know-how) are not protected by patents.

KEY WORDS: Know-how, licensing, patents

J.E.L. classification: 034, L14

1. INTRODUCTION

This paper starts from the premise that a key variable affecting the rate of economic growth is the efficacy with which new technologies are utilized in the economy (Rosenberg *et al.* [1992]). Technology licensing is an important mechanism of transferring technology so that agents other than the innovator can utilize technology. Unfortunately, most of the theoretical literature on licensing assumes that all technical knowledge is contained in patents or formulae, and that technology transfer has no real cost and amounts to little more than the permission to infringe patents.[1] Instead, efficient technology transfer usually also requires the transfer of know-how, often uncodified and costly to transfer. Third parties are unlikely to be able to verify the transfer of know-how, except possibly at a very high cost. That raises the question: Can know-how be transferred through arms-length contracts, even in the absence of verification by courts?

I show that a key to the success of the arms-length contracts is the complementarity between know-how and patents: know-how is more valuable when used in conjunction with the codified (patented) components of the technology. This complementarity allows the licensor to use the protection accorded to the codified components of the technology, *i.e.* the patent, to protect himself against opportunistic be-

[1]Bhattacharya *et al.* [1990] assume that all technological knowledge codified so that sharing (or transferring) such knowledge is costless and verifiable by third parties. Similar assumptions are made in Gallini and Wright [1990], Gallini and Winter [1985], and Katz and Shapiro [1986].

haviour by the licensee. The timing of payments in the contract allows the licensee to protect herself. Thus simple contracts involving patents can accomplish the transfer of know-how.

The traditional role of patents has been thought to be one of providing incentives to innovate by preventing imitation, albeit at the cost of restricting the diffusion of the technology. An important conclusion of this paper is that broader patents improve the efficiency of technology transfer, even of parts of technology that are not protected by patents.[2] The model not only explains how costly know-how is transferred, it also explains a number of characteristics of licensing contracts. It explains the bundling of patents and know-how in one licensing contract and predicts that the amount of know-how provided is increasing in the lump sum payments.[3]

The paper is organized as follows. Section 2 discusses the contracting problems implicit in the sale of know-how. Section 3 introduces the basic model and notation, and discusses the intuition behind the results and their implications. It contains the main proposition of this paper, concerning the relationship between strength of intellectual property rights (IPR henceforth) and transfer of know- how through arms length contracts. The robustness of this relationship is analyzed in the following sections. Section 4 extends the analysis to allow for renegotiation. Section 5 analyses the case of one sided asymmetric information about the ability of the licensee, with and without renegotiations. Major policy implications and future extensions are discussed in section 6, which concludes the paper.

2. OPPORTUNISTIC BEHAVIOUR IN LICENSING OF KNOW-HOW

Technology licensing involves more than just the permission to use the knowledge covered by patents: In many cases, the information required for successful utilization extends even beyond blueprints, drawings, and specifications and includes heuristics, rules of thumb, and other "tricks of the trade". These routines and rules of thumb arise as a firm develop their technology base over a long period, often through trial and error type search processes (Sahal [1981]; see also Nelson [1990], and Pavitt [1987].). A large fraction of knowledge thus acquired is tacit (i.e. not written down). In this paper I shall assume, largely for purposes of exposition, that all know-how is kept tacit.[4]

The transfer of know-how is especially important when the firm that is licensing in the technology does not have a great deal of experience with that particular class of technologies—in international technology transfer (especially North-South trans-

[2] Ed Steinmueller has pointed out to me that know-how can be protected under common law under trade secrets.

[3] Using data on Indian technology imports, I show that technical services are more likely to be provided when the contract includes a patent agreement (Arora [1994]). Scott-Kemmis and Bell [1988], and Contractor [1981] provide evidence that know-how transferred is increasing in the lump-sum payments by the licensee.

[4] On the notions of tacit and codified knowledge, see Svennilson [1964], Polanyi [1966], and Nelson and Winter [1982]. Know-how that is not tacit can easily be accommodated, with the possible difference that the costs, to the licensor, of transferring codified know-how would be lower. For further discussion of codifying versus not codifying see Dasgupta and David [1990], and David [1992].

fer), where undeveloped technologies are transferred (*e.g.* biotechnology), and in transfers across industrial sectors.[5]

The question of know- how has been largely neglected in the theoretical literature on licensing, even though there is a great deal of empirical evidence that points to its importance. For instance, over two thirds of a sample of UK firms reported that "most"or "all"their license agreements had know-how provisions (Taylor and Silberston [1973]). In his study of international technology licensing, Contractor [1981] shows that the principal criterion used by licensors for determining payments was the extent of technical services provided to the licensee.

The transfer of know-how, especially tacit know-how, is costly because the transfer is usually accomplished through the training of personnel, trips by the engineers of the licensor and other services, often called technical services. (Teece [1977], Contractor [1981].) The quality or the extent of such services may vary according to the efforts made by the licensor. Even though the parties involved can observe the quality and extent of the services, third parties such as courts are unlikely to be able to verify adequately variations in quality, especially after the know-how has been transferred. Verification may require monitoring of the process, which is likely to be prohibitively costly.[6]

If third party verification is difficult, both sides may behave opportunistically. Once the know-how is transferred, the buyer may try to avoid paying for it, since it would be difficult to force her to "unlearn"what she has been taught. On the other side, given the cost of transferring know-how, the licensor may be tempted to skimp on the know-how provided. This double sided opportunism is an important impediment to efficient transfer of technology. Faced with the possibility of opportunism, one can always reach the optimum by "selling the firm"—*i.e.* letting the licensor be the residual claimant. Letting the licensor be the residual claimant may not be feasible because usually the licensee would also provide complementary inputs, which the licensor may lack, for the commercialization of the technology. For instance, the licensor may be a small research intensive biotech firm which lacks the ability to conduct expensive clinical trials required by the FDA. There may also be legal problems such as anti-trust (domestic licensing) or restrictions on foreign investment (in-

[5] Spitz [1988: 329] provides a very interesting example of the importance of know-how even to technologically competent firms. In the 1950s Spitz headed a team of chemical engineers from Scientific Design, a pioneering chemical process design company. The team was supposed to design and build a 20 million lbs per year plant for phthalic anhydride. The patents were held by a German company. Even though the team had access to the patents, and a great deal of technical information about the German process had been made public by the Allied forces after WWII, Spitz reports that the team faced a number of problems with the plant, such as leaks from pipes, accumulation of gasses, and fires and explosions. Eventually, a consultant who had worked in a phthalic anhydride plant had to be called in to set matters right. Hounshell and Smith [1988] provide evidence that Scientific Design was not alone in its inability to utilize German technology without the benefit of know-how.

[6] An anonymous referee raised the issue of how know-how could be observed by the two parties but not by courts. An analogy with the master craftsman—apprentice situation may be useful in understanding this point. An apprentice will be able to observe and appreciate the tacit knowledge that is being imparted to him by the master craftsman. A third party will be unable to verify this unless the latter observed the interaction between the master and the apprentice over a sustained period. Such observation may be prohibitively costly. Formally, what is required is that while third party enforceable contracts on know-how are not possible, licensees can observe either the amount, or the value of the know-how being transferred to them. Further, the cost of transferring know-how should be common knowledge to both the licensee and the licensor.

ternational licensing).[7] Reputation or long term relationships may be other means by which the problem may be ameliorated. However, many licensing contracts do not involve repeated licensing or long term relationships.

3. THE BASIC MODEL

In this paper I focus on the role that patents in overcoming the problem raised by the double sided opportunism. Using a simple Principal-Agent model I show that simple contracts, where know-how is bundled with codified technology, can successfully achieve the transfer of know-how. However the efficiency of such contracts and the rents that the licensor gets, depend upon the strength of IPRs.

For ease of exposition, patents will be assumed to be the only kind of intellectual property, and patent scope the (sole) measure of the strength of the IPR regime. I model patent scope as increasing the cost of "inventing around"(*cf.* Gallini [1992]). To focus upon the role of patents, I examine contracts with only lump sum payments.[8] The available evidence also suggests that know-sales are more closely related to lump sum payments. Royalty rates tend to vary very little across licensing contracts for any given industries. By contrast, there are large variations in the lump sum payments, which are said to reflect differences in the amount of know-how being transferred. (Bidault [1989], Taylor and Silberston [1973: 20], Contractor [1981].)

Lump sum payments are made in two stages: The licensee makes part of the payment after the contract is agreed upon but before any know-how is transferred. The rest of the payment is made when the licensor has provided the know-how. The licensee can withhold the second period payment, and thus can guard herself against the possibility of the licensor under-supplying know- how. The licensor can withdraw the patent (*i.e.* deny the licensee any right to use the patent) if he is not satisfied with the licensee's behavior. Here the assumption that know-how is complementary to the patented component of technology is crucial (see assumption 3.ii below). As the example in footnote 5 suggests, know-how tends to be highly application and context specific.[9] Therefore, the value of the know-how to the licensee will be higher if used together with the patented component of the technology. The mutual "hostage taking"allows a self enforcing contract in know-how to work, even though no externally enforceable contract exists. This intuition is formalised below.

■ *Definitions and notation*

1. I represent by x, the amount of the know-how transferred by the licensor to the licensee, where x is assumed to lie in some real interval, $[0, X]$.
2. $C(x)$ is the cost of transferring know-how borne by the licensor.
3. $V(x)$ is the payoff to the licensee gross of the payments to the licensor.

[7] Gallini and Winter [1985], and Katz and Shapiro [1985] examine the issues raised by licensing to rivals. In contrast, I assume that the licensor and the licensee do not compete in the product market.

[8] Royalty payments also create a situation to familiar Marshallian share-cropping problem and are a second-best solution. Furthermore, as shown below, contracts with lump sum payments alone can maximize the joint surplus. Output based royalties may not be feasible where the licensor cannot observe the output of the licensee.

[9] Note that some of the know-how of the firm may be quite general, and will therfore, not be specific to the firm's technology. This paper is concerned with the part that is firm specific.

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2. $V(x)$, and $L(x)$
3. $V(x) > L(x) >$
   $V_x(x) > L_x(x)$

Part (i) says that
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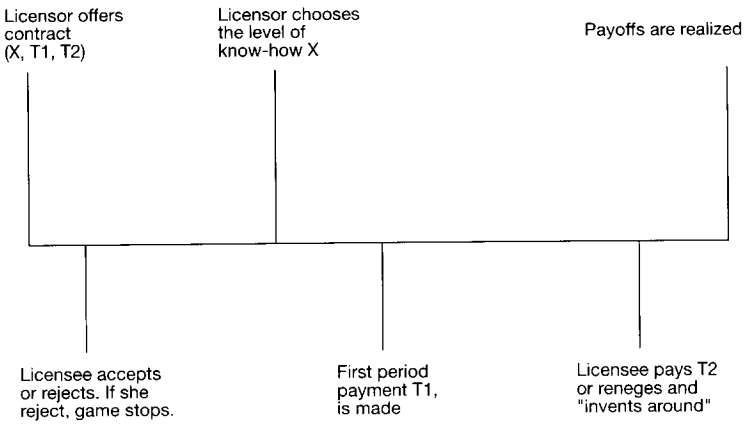

4. L(x) is the maximized payoff to the licensee if the contract is terminated and she cannot use the patented part of the technology of the licensor. Since the licensee may choose to "invent around"the patent, L(x) is at least as great as the payoff from "inventing around". (Assumption 3.i below implies that if the contract is terminated, the licensee would always "invent around"*i.e* imitate without infringing the patent of the licensor. Therefore, L(x) is equal to the payoff to the licensee from inventing around the patents of the licensor, if the contract is terminated.)

The following assumptions are made on these functions.

1. $C(0) = 0, C_x > 0$ *i.e.* the marginal costs of transferring know-how are positive.
2. V(x), and L(x) are non decreasing in their arguments. L(0) = 0.
3. $V(x) > L(x) > 0 \quad \forall \quad x$ (i)
   $V_x(x) > L_x(x) > 0 \quad \forall \quad x$ (ii)

Part (i) says that patent rights are valuable and that if the contract is terminated, the licensee will always invent around. Part (ii) assumes that the marginal value of know-how is higher when it is used together with the patented part of the technology (Bulow *et. al.* [1985]).

Since the formal structure of the problem is quite straightforward, for simplicity I shall characterize an equilibrium somewhat informally in terms of the contract that is chosen by the licensor. Thus for instance, in the later sections, in place of separating equilibrium, I use the term separating contract. The contracting is assumed to unfold as follows. (See figure.) In the first period, the licensor offers a contract $\{T^1, T^2, x\}$, where the licensee agrees to pay T^1 immediately, and then pay T^2 after the licensor has provided x, in the second period. If the contract is accepted, then the licensor supplies the know-how after the first period payments have been made. *Note well that by assumption, the provision of* x *is not monitored by a third party; it is observed by the two contracting parties. Hence, although I have included* x *in the contract, it is to be understood throughout that no externally enforceable contract is written on the provision of* x, *and neither can any formal commitment be made on* x. In-

stead, the contract allows either party to terminate the contract if they are not satisfied with the behavior of the other.[10]

The termination of the contract would imply that the licensee would lose the right to use the patents of the licensor. Thus, if the licensee wished to produce, she would have to invent around the licensor's patents. The licensee cannot, however, be forced to unlearn: If the contract is terminated, the licensee would naturally like to make use of what she has learnt through the technological know-how to invent around the patents of the licensor. The payoff from inventing around, $L(x)$, will depend upon two factors. First, it is decreasing in the extent of complementarity between the knowledge in the patents and the know-how. Second, $L(x)$ is decreasing in the scope (breadth) of the patent.[11]

■ *Basic Model with symmetric information and no renegotiation*

Consider first the case where the licensor can commit not to renegotiate the second period payment after x has been supplied. *This is the only kind of commitment that I shall consider.* It will be convenient first to restrict our attention to paths where the licensor does not wish for the licensee to invent around. I show in *fn* 13 that this would be true of all equilibrium outcomes.

As is customary, I shall begin with the last stage of the game. In the final stage, the licensee considers whether to honor the contract or to renege. By assumption, the licensor has committed not to renegotiate the second period payment. Therefore, the licensee will make the second period payment if and only if $V(x) - T^2 \geq L(x)$. However, in any equilibrium, the licensor supplies (and hence can only credibly promise) x which satisfies the equation $V(x) - T^2 = L(x)$.[12] If the inequality were strict the "promise"of x would not be credible, and thus, in the first stage, the licensee would not make the full first period payment. Since the licensor is assumed to have the power to make "take-it-or-leave-it"offers, he can credibly promise to provide the joint surplus maximizing amount of know-how, and extract *ex ante*, through the first period payments, the second period rents accruing to the licensee.

Normalizing the licensee's reservation utility to zero, we can now solve for the equilibrium contract. The licensor chooses $\{T^1, T^2, x\}$ to maximize $[T^1 + T^2 - C(x)]$, subject to the following constraints:

[10] This provision is often found in licensing contracts. An alternative interpretation is that since courts will not be able to determine which party was guilty of a breach of the contract, in practice, if either party were to renege on the contract, there is not much the other party can hope to achieve by way of legal redress. In an earlier version of this paper, I allowed for liquidation damages to be paid if the contract were terminated. It turns out that they are not important and have been neglected for ease of exposition.

[11] Arrow [1962b] notes that imitation without infringement is costly. Merges and Nelson [1991] cite the example of the Selden patents (automobiles) and the Wright patents (aircraft). In both cases, the patents were broad and the authors claim that this raised the costs for other producers. Levin *et al.* [1987] provide evidence that suggests that patent protection raises imitation costs as well as royalty income from licensing.

[12] Suppose the inequality were strict. In the second period, given T^1 and T^2, the licensor could reduce the know-how supplied by Δx (such that the inequality still holds) and the licensee would still agree to pay T^2. If so, the licensor's payoffs would increase by the amount $C_x\Delta x$, but those of the licensee would decrease by $V_x\Delta x$. Thus the strict inequality cannot hold in equilibrium. I assume that the equation $V(x) - L(x) = T$ has a unique solution for all $T > 0$.

$$V(x) - T^2 = L(x) \tag{1.1}$$

$$T^2 - C(x) \geq 0 \tag{1.2}$$

$$V(x) - T^1 - T^2 \geq 0 \tag{1.3}$$

Constraint (1.1), the "no-reneging"constraint, has been derived above from the second stage of the game. The second constraint ensures that the second period payment to the licensor covers the licensor's cost of transferring know-how, so that the latter has the incentive to participate in the second stage of the game. Constraint (1.3) is the overall participation constraint (also called the individual rationality constraint) for the licensee.

Keeping in mind that (1.3) will always bind in any equilibrium (because the licensor can always increase the first period payment appropriately), and substituting (1.1) and (1.3), one can easily show that the licensor's problem can be rewritten so that he maximizes the joint surplus, albeit subject to a constraint.

$$\max_x \; V(x) - C(x)$$

$$s.t.$$

$$V(x) - L(x) - C(x) \geq 0 \tag{2.1}$$

...(2)

The substitution of the constraints (1.1) and (1.3) also implies that

$$T^2 = V(x) - L(x)$$

$$T^1 = L(x) \qquad \ldots(3)$$

From (3) we see that although the licensee manages to get some rents in the second period, these are extracted *ex ante* through the first period payments.[13]

In order to analyze the effects of patent scope, it is helpful to parameterize by expressing the payoff from "inventing around"as a fraction of the gross payoff. Suppose we can write $L(x) = kV(x)$, $0 < k < 1$. Given the level of complementarity between the patented technology and know-how, an increase in k represents a decrease in patent scope. Define x^* to be such that it maximizes $V(x) - C(x)$, *i.e.* x^* is the joint surplus maximizing level of know-how. It follows that for k sufficiently small, $(1 - k)V(x^*) - C(x^*) > 0$. This shows that if patent scope is broad enough, then x^* is the solution to (2). Moreover, if (2.1) binds, then x is decreasing in k. This gives us the main proposition of the paper.

[13] One can now easily see why there would be no inventing around by the licensee in a perfect equilibrium. Consider a possible equilibrium path where the licensee invents around. Given this, it is optimal for the licensor to provide $x = 0$ at the second stage for the latter's payoffs are given by $C(0) = Max\ \{-C(x)\}$. If so, the licensee would at the first stage be willing to pay no more than $L(0)$. The licensor's total payoffs are then given by $L(0) - C(0)$. Compare this to the payoff received by the licensor when the licensee does not "invent around", given by (2). The latter are easily seen to be greater than $L(x^*) - C(x^*)$, which in turn is greater than $L(0) - C(0)$. The simple intuition is that there are gains from trade in know-how; inventing around will not allow those gains to be realised.

Proposition 1. Simple lump sum based contracts can achieve the transfer of the first best (joint surplus maximizing) amount of know-how if the patent scope is sufficiently broad. For narrow patents, the amount of know-how transferred is increasing in patent scope.

■ *Discussion and policy implications of proposition 1*

Though very simple, this model does have strong implications. The model explains why patent and know-how contracts are bundled together, even though the majority of the licensees claim that they are mainly interested in know-how.[14] Second, this model explains why technology licensing may be an inefficient means of extracting rents from innovation.[15] Arrow [1962b: 355] notes that:

> Patent royalties are generally so low that the profits from exploiting one's own invention are not appreciably greater than those derived from the use of others' knowledge. It really calls for some explanation why the firm that has developed the knowledge cannot demand a greater share of the resulting profits.

As k approaches 1, x approaches 0—as patent scope narrows, the amount of know-how transferred tends to fall below the first best level. As x falls, so does the net return to the licensor: both the first and the second period payments fall. If exploiting an innovation requires know-how, then unless patents are broad enough, the transfer of know-how will not be efficient in licensing contracts. In the context of innovation policy, the model suggests that broader patent scope would be beneficial to the extent that the chief sources of innovation are small, research intensive firms which rely upon licensing.

Third, the model implies that if there exists a sufficiently broad scope of protection for (codified) intellectual property, then the joint surplus maximizing amount of tacit know-how is contracted for and provided.[16] In a policy context, the controversy over intellectual property rights in forums such as the GATT has received a great deal of attention. Chin and Grossman [1990] have pointed to the potential benefits of stronger patent protection to the South (in addition to the North) arising from a higher rate of innovation in the North. Proposition 1 implies that stronger patent protection would benefit the South by increasing the flow of know-how, even without any incremental inducement to innovation in the North.

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[14] ...Many industrialists whom we consulted said quite categorically that the main purpose of licensing is to exchange know-how etc., with patents a minor consideration added in the small print at the end of the agreement to lend an extra element of precision and security to the contract." (Taylor and Silberston [1973: 114]).

[15] Typical explanations have pointed to the problem of establishing the value of information without complete disclosure. This paper focusses on a related case, where the issue is not the value of information (which is assumed to be known to both parties) but the problem of opportunistic behaviour by both the seller and the buyer.

[16] Steinmueller [1989] makes the same point. Klemperer [1990] investigates the role of patents in balancing the inducement to innovate with the social cost of monopoly. Scotchmer and Green [1990] examine the closely related issue of novelty requirement and find that a weak novelty requirement would in general be preferred. Similarly, Merges and Nelson [1991] argue from an evolutionary perspective that narrower patents are preferred where technological progress is cumulative. In a recent paper, Gallini [1992] finds that broad and short lived patents are superior. Licensing possibilities are not considered in any of the studies.

How sensitive are these conclusions to the specific assumptions of the model? In the following sections I relax the assumption that the licensor can commit not to renegotiate. I also allow the licensee to have superior information about her (licensee's) ability to utilize the technology. The results obtained earlier are fairly robust to these extensions.

4. EXTENSIONS: RENEGOTIATION PROOF CONTRACTS

One problem with the model just discussed is that the contracts are not renegotiation proof in the following sense. Suppose for some reason, the licensor undersupplies know-how at the second stage. Even though the licensee would not be willing to make the previously agreed upon second period payments, instead of terminating the contract, she could offer to renegotiate the second period payments. As shown below, this would result in lower second period payments. Therefore, in the absence of *ex-ante* commitment not to renegotiate, the licensor will undersupply know-how compared to the baseline case, and anticipating this, the licensee would not be willing to pay the high first period payment.[17]

If the licensor is unable to commit not to renegotiate, then the second period payment and the know-how will be determined jointly. Assume as before that the licensor can make a "take-it-or-leave-it"offer. The maximum amount that the licensee would be willing to pay at the second stage, *given* x, is given by

$$T^2 = V(x) - L(x)\ldots. \tag{4}$$

Now consider the licensor's choice of x. The extent of know-how transferred, x, is given by

$$argmax\ [V(x) - L(x)] - C(x) \qquad \ldots.(5)$$

From (5) one can see that x is below first best levels. The first and second period payments are given by (3). Since x is less than x^*, both period payments are lower than the baseline case. The effect of a decrease in k (increase in patent scope) is given by

$$\left[\frac{\partial x}{\partial k}\right] = \left[\frac{V_x(x,\theta)}{V_{xx}(x,\theta)(1-k) - C_{xx}(x)}\right]. < 0,$$

where the denominator is negative by the assumption of an interior maximum

$$\left[\frac{\partial T^2}{\partial k}\right] = V_x(x,\theta)(1-k)\left(\frac{\partial x}{\partial k}\right) - V(x,\theta) < 0$$

$$\left[\frac{\partial (T^1+T^2)}{\partial k}\right] = V_x(x,\theta)\left(\frac{\partial x}{\partial k}\right) < 0.$$

These results are summarized in proposition 2.

[17] This is really an assumption about what happens off the equilibrium path, because the contracts are not renegotiated in equilibrium. However, as is well know in non-cooperative game theory, the assumption changes significantly the nature of the equilibrium outcome.

Proposition 2. When the licensor cannot commit not to renegotiate the contract after the know- how has been supplied, then the amount of know-how supplied is less than the first best level. Moreover, the total payment, the second period payment, as well as the amount of know-how, are increasing in patent scope.

■ *Discussion and extensions to bargaining*

Proposition 2 points to the important role of commitment and (indirectly) of the relative bargaining power of the two agents. The second period payments by the licensee reflect the latter's value of reneging and inventing around the patent. Since the value of inventing around is increasing in the amount to know-how supplied by the licensor, the licensor incurs an extra "cost"of supplying the know-how: apart from the direct costs, he also loses some of the second period rents by making it easier for the licensee to invent around.

The extension to renegotiation also points to the how the outcome would change if one were to make a different assumption about the distribution of bargaining power. It is easy to show that the greater the bargaining power of the licensee, the lower the second (and first) period payment and the lower the amount of know-how transferred. This implies that the weaker the bargaining power of a licensor, the greater must be the breadth of the patent in order for arms length contracts to be effective. Thus proposition 2 provides further insight into the question of why licensing may not be an efficient strategy of rent appropriation, especially for smaller firms.

5. EXTENSIONS: ASYMMETRIC INFORMATION ABOUT THE ABILITY OF THE LICENSEE

Licensees may differ in the value they place upon know-how. When these differences are not observed by the licensor and are private information to the licensee, one may ask if the analysis of the previous section would still be relevant.[18] In this sub-section I show that even with the licensee having private information, the simple contracts discussed in this paper can still accomplish the transfer of know-how, albeit at below joint surplus maximizing levels. What is remarkable is that the inefficiency is, for the most part, not due to the non-contractibility of know-how, but rather due solely to private information.

Let θ index the value of the know-how to the licensee. A high θ can be thought of as being the case where the licensee can supply the complementary resources needed for commercialization of the technology at a lower cost, and thus has a higher valuation of the know-how provided by the licensor. Suppose there are two types of licensees indexed by H and L, $\theta_H > \theta_L$. Suppose that the licensor does not observe θ and let p be the subjective probability that the licensor attaches to the event that $\theta = \theta_H$. In order to analyze the asymmetric information case I shall need to make one further assumption.

[18] Gallini and Wright [1990] analyze the case for where the licensor has superior information about the quality of the technology. I do not analyse this possibility here.

4. $V_\theta(x, \theta) > L_\theta(x, \theta) > 0$

$V_{\theta x}(x, \theta) > L_{\theta x}(x, \theta) > 0$

The assumption states that the *increase* in the marginal payoff to know-how, due to the greater technological capability of the licensee, is higher when the know-how is used in conjunction with the patented components of technology. This assumption is crucial to what follows and is analogous to the "single crossing property" invoked in many adverse selection Principal-Agent models.[19] Using the result that self-enforcing contracts on x exist, I show that the licensor can offer a menu of contracts that allow the two types of licensees to self-select.

Proposition 3. When licensees have different abilities which are not observed by the licensor, unless patent scope is either very narrow or very broad, the level of know-how transferred is the same as when the licensor can write externally enforceable contracts upon the provision of x. First period payments act as screening devices, with more capable licensees signalling their type by agreeing to higher first period payments.

Proof: There are two cases to be analyzed–with and without commitment on renegotiation, and the proofs are provided below in the form of lemmata for each case.

■ *Case 1: Asymmetric information, without renegotiation*

The symmetric information case analyzed in section 3 shows that even if x is not observed by third parties, the ability of the licensor to commit *ex ante* not to renegotiate a contract implies that self- enforcing contracts can be written on x. This property is useful because it enables us to write the licensor's problem as

$$\underset{T_i^1, T_i^2, x_i}{Max} \sum_i p_i(T_i^2 - C(x_i) + T_i^1) \qquad i = H, L.$$

$$s.t.$$

$$V(x_i, \theta_i) - T_i^2 - T_i^1 \geq Max\{[L(x_j, \theta_i) - T_j^1], [V(x_j, \theta_i) - T_j^1 - T_i^2]\} \quad \ldots(6.1)$$

$$V(x_i, \theta_i) - T_i^1 - T_i^2 \geq 0 \quad \ldots\ldots(6.2)$$

$$V(x_i, \theta_i) - L(x_i, \theta_i) = T_i^2 \quad \ldots\ldots(6.3)$$

$$i \neq j;\ x_i \equiv x(\theta_i) \qquad \ldots(6)$$

Constraint (6.3) says that x must be chosen by the licensor subject to no-inventing-around constraint, similar to constraint (1.1). The individual rationality constraints are given by (6.2). Finally, (6.1) represents the truth telling constraint which takes

[19] Baron and Myerson [1982] is a standard reference for Principal Agent models. Cooper [1984] provides a useful survey of a general class of adverse selection models, and alo discusses the "single crossing" property.

into account the possibility that the licensee could renege after accepting the contract.

Lemma 1. The unique Bayes-Perfect equilibrium of the licensing game is a separating equilibrium characterized by

$$x(\theta_H) = argmax\ V(x, \theta_H) - C(x);$$

$$x(\theta_L) \text{ is given by : } V_x(x,\theta_L) - C_x(x) = \left(\frac{p}{1-p}\right)[V_x(x, \theta_H) - V_x(x, \theta_L)]$$

$$T_L^1 = L(x(\theta_L), \theta_L)$$

$$T_H^1 = L(x(\theta_H), \theta_H) - [V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L)]$$

$$T_i^2 = V(x(\theta_i), \theta_i) - L(x(\theta_i), \theta_i), \quad i = H, L \qquad \ldots(7)$$

Remark: Proofs are to be found in the appendix. If the incentive constraint of the L type does not bind then the optimal contract is a separating contract (i.e. induces a separating equilibrium) where the outcome does not depend upon patent scope. In fact, the outcome is identical to the separating equilibrium of the standard model where x is contractible. If x were contractible, the H type would get the first best level of know-how while the L type would get less than its joint surplus maximizing level. Further, the H type would enjoy information rents.

When will the incentive constraint for the L type bind? It binds if k is either too large, or too small.

Recall that x^* (θ) is the joint surplus maximising level

$$\text{Define } k^* = \left[\frac{V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L)}{V(x(\theta_H), \theta_H) - V(x(\theta_H), \theta_L)}\right] \text{ where } x(\theta_H), x(\theta_L) \text{ are given by (7).}$$

Also define $K = Min\ \{K_H, K_L,\}$ where

$$K_i \text{ is given by } V(x^*(\theta_i), \theta_i)\ (1-K_i) = C(x^*(\theta_i)), \quad i = H, L \qquad \ldots(8)$$

Lemma 2. If θ is private information to the licensee, and $L(x, \theta) = kV(x, \theta)$, and the licensor can commit not to renegotiate, then the incentive constraint of the L type will not bind for k in the range $[k^*, K]$, $K < 1$. This is also the range of k that maximises the joint surplus.

Remark: The analysis thus far shows that unless patents are very narrow or very broad, private information to the licensee does not create special problems for the transfer of know-how. If patents are very narrow, then proposition 1 shows that inefficiencies will result. It also shows how the general conclusion in favor of broad patents is modified when the licensee has private information. Very broad patents raise the cost of inducing separation. The non-contractibility of x implies that the licensee is left some rents in the second period which are extracted through first period payments. With the licensee having private information, the licensor must guard against the possibility of the L type misrepresenting and then going on to terminate

the contract in the second period. Hence the information rents enjoyed by the H type have to also be low enough to satisfy the "truth-telling"and the "no-inventing-around"constraints of the L type. As inventing around becomes costlier, the *difference* between the second period rents of the two types becomes smaller. To maintain the inequality, the information rents must be reduced ($x(\theta_L)$ must be decreased), and the difference between the second period rents increased ($x(\theta_H)$ must be increased). Notice that although x is not contractible, we still get the outcome that the H type pays a higher first period disclosure fee than the L type, and receives more know-how than the L type. In other words, the model predicts that licensees with greater ability to utilize the technology will be willing to make greater payments up front.

■ *Case 2: Asymmetric information with renegotiation:*

In contrast to the case where the licensor could commit not to renegotiate, now x cannot be used as a screening instrument. Instead, the licensor must rely solely on the first period payments. This implies, amongst other things, that separating contracts may not always exist.

Define $x(\theta_H) = argmax\ [V(x, \theta_H) - L(x, \theta_H)] - C(x)$ and $x(\theta_L)$ similarly...(9)[20]

Once separation has been achieved, x is determined by (9) so that in all separating contracts, the amount of know-how that any given type receives does not vary across contracts, implying that there are no distortions induced by the need to induce separation. This gives us the following:

Lemma 3. When renegotiation is possible and is private information to the licensee, (i) separation is feasible *iff* $L(x(\theta_H), \theta_H) - L(x(\theta_H), \theta_L) > V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L)$. If separation is feasible, then the licensor will always choose a (unique) separating contract. The best separating contract has $T^1(\theta_H) = L(x(\theta_H), \theta_H) - [V(x(\theta_L), \theta_H) - Vx(\theta_L), \theta_L)]$; $T^1(\theta_L) = L(x(\theta_L), \theta_L)$. *(ii)* If separation is not feasible then the best contract (for the licensor) is the same as that under symmetric information for $\theta = \theta_L$.

Lemma 4. When renegotiation is possible and θ is private information, there exists $k^{**} > 0$, such that $k < k^{**}$ implies that separation is not feasible.

Remark: The first period payments play a critical role in inducing separation. By agreeing to make a higher first period payment, the more capable licensee signals her type, thereby inducing a higher flow of technological know-how. As in the *ex ante* commitment case, very broad or very narrow patent scope causes inefficiencies. In this case, with very broad patent scope, separation is not feasible because the second period rents that licensees are left become too small, and since the second period payments are not a control variable, separation is not possible. As shown in proposition 1, very narrow patent scope exacerbate the inefficiencies due to opportunism. Both result in the transfer of sub-optimal levels of know-how.

[20]The reader is alerted to a mild abuse of notation, for $x(\theta_i)$ is now the solution to a slightly different problem from that defined in (7) in lemma 1.

6. SUMMARY AND CONCLUDING OBSERVATIONS

Much of the literature in economics has viewed technology as easy to codify and costless to transfer. This paper adopts a different conceptualization. Utilizing technology requires a great deal of know- how. Transferring know-how through arms-length transactions raises problems because know-how is difficult to codify. Therefore the transfer of know-how is costly, and it is difficult for third parties such as courts to monitor the transfer of know-how.

In this paper I have analyzed the role that Intellectual Property Rights (IPRs) can play in overcoming the problem of double sided opportunism. The paper develops a model that shows that the amount of know-how transferred depends positively on the strength of the IPR regime. The model predicts that the transfer of know-how can be accomplished by contracts utilizing lump sum payments alone. It also predicts that these lump sum payments will be increasing in the amount of the know-how transferred. The model shows that lump sum payments can have significant allocation effects: first period payments, often called disclosure payments, are used by as screening devices by licensors to screen out lower capability licensees. Thus, higher lump sum payments induce greater know-how flow. These predictions are not only consistent with the available evidence, they also suggest that future empirical work on licensing contracts pay attention to the contracting mechanisms by which know-how transfer is accomplished.

The model analyzed here can be extended to the case where technological inputs are provided by both parties. Similarly, although I have shown that how the model generalizes to cases where the second period payments can be re-negotiated, and where the licensee has superior information, further research is needed to analyze the case where the licensor also has some private information, and where the contract includes both output royalties and lump sum payments.

The paper provides insights into the institutional form of the division of labor in inventive activity. We know that patents are not very effective against imitation in many industries (Levin *et al* [1987]). In such cases vertical integration or joint-ventures may be required to facilitate the transfer of know- how. Therefore, an important benefit of broader patents would be to encourage innovation by research intensive firms, such as small biotechnology firms, which lack the capabilities for commercializing innovations. For such firms, the expected revenues from licensing the innovation would be an important part of the payoff, and a policy that enhances the efficiency of the market for know-how would increase their incentives to invest in new knowledge. In the international context, better IPR laws in countries which rely upon licensing (as opposed to direct foreign investment) as a source of technology transfer would enhance the inflow of know-how and make the technology transfer more efficient.

I do not mean to suggest that there are no disadvantages of broader patents. In innovation, if for some reason contracting is excessively costly, broader patents may inhibit the development of technologies that have a strong cumulative nature. In international technology transfer, stronger patent protection may increase the share of the rents of the North vis a vis the South. Stronger patent protection may also increase the market power of licensees in the markets of the South. The point being made is simply that a major benefit, hitherto unnoticed, of broader patents would be that complementary know-how, critical to the utilization of technologies, could be bought and sold more efficiently. An important task for future research is to attempt to integrate the different effects to make a systematic welfare analysis possible.

APPENDIX: PRO

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APPENDIX: PROOFS

Proof of Lemma 1

Using (6.3) we can simplify the incentive constraints by noting that if the licensee were to deviate, then the two types would choose different courses of action. Substituting (6.3) in the RHS of (6.1), we can write the RHS of (6.1) as

$$Max\{[V(x(\theta_j), \theta_i) - V(x(\theta_j), \theta_j) + L(x(\theta_j), \theta_j) - T_j^1], [L(x(\theta_j), \theta_i) - T_j^1]\} \quad \ldots(A1)$$

Using the assumption that $V_{x\theta} > L_{x\theta}$, it is easy to see that for type L, the first term in (A1) is larger than the second term. Hence type L would always refuse the "take-it-or-leave-it" offer of paying T_H^2 in the second period *if she were to deviate.* For type H, the second term is larger. Substituting this result and (6.3), one can then rewrite (6) as

$$\underset{\{T_H^1, T_L^1, x(\theta_H), x(\theta_L)\}}{Max}$$

$$p_H[V(x(\theta_H), \theta_H) - L(x(\theta_H), \theta_H) - C(x(\theta_H)) + T_H^1] + (1-p_H)[V(x(\theta_L), \theta_L) - L(x(\theta_L), \theta_L) - C(x(\theta_L) + T_L^1]$$

$$s.t.$$

$$(ia) \quad L(x(\theta_H), \theta_H) - T_H^1 \geq V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L) + L(x(\theta_L), \theta_L) - T_L^1$$

$$(ib) \quad L(x(\theta_L), \theta_L) - T_L^1 \geq L(x(\theta_H), \theta_L) - T_H^1$$

$$(iia) \quad L(x(\theta_H), \theta_H) - T_H^1 \geq 0$$

$$(iib) \quad L(x(\theta_L), \theta_L) - T_L^1 \geq 0 \quad \ldots(A2)$$

Constraint (A2.ia) is the combined truth telling and no-inventing-around constraint for the H type, henceforth also called the incentive constraint, and similarly, (A2.ib) is for the L type. The other two constraints are the participation constraints. This is very similar to a standard adverse selection model. If the incentive constraint for the L type does not bind, we get the outcome characterized in lemma 1. If the incentive constraint of the L type does bind, then $x(\theta_H)$ is greater than first-best level, and $x(\theta_L)$ is smaller than even the sub-optimal level defined by lemma 1.

To prove that the unique Bayes Perfect equilibrium is a separating equilibrium, two questions need to be settled. First, Could the licensor ever do better by pooling instead of by inducing separation? The best pooling equilibrium from the point of view of the licensor is the symmetric information contract for $\theta = \theta_L$. The reason is that if the licensor cannot distinguish between the two types, and if he cannot, by assumption, offer a contract that violates the rationality constraint of the L type, then the best he can do is offer the optimal symmetric information contract for the L type.[1] This contract satisfies all the constraints in (A2) and therefore, by defini-

[1] The optimal symmetric information contract for the H type would violate the rationality constraint of the L type because the total payments made by the licensee exceed the total gross payoffs that would

tion, yields a lower payoff than the optimal separating contract characterized above. Therefore, pooling cannot be optimal under the assumptions made here.

Second, Is it possible to have an equilibrium contract where a particular type would terminate the contract (*i.e.* invent around) in the second period? The answer is No, and the reasoning is similar to that for the symmetric information case discussed in the text. Formally, note that a contract that would induce the licensee to invent around in the second period is equivalent to having a contract with $x = 0$, and $T^2 = 0$, when there two types separate. Thus, if the two types separate, this contract is dominated by the optimal separating contract. It is also easy to see that there would not be any inventing around in a pooling contract.

The only possibility that remains is of a semi-separating equilibrium where the L type randomizes.[2] If semi-separating equilibria can be ruled out, then one would have ruled out the possibility of the licensee inventing around in equilibrium. In turn this would show that the optimal strategy for the licensor is to offer the contract that has been called the optimal separating contract, and characterized in lemma 1 in the text, and is therefore also the unique bayesian perfect equilibrium of the game in question. In a semi-separating equilibrium, the L type must be indifferent between the two contracts. A small increasè in $x(\theta_H)$ and in $T_H{}^1$, $T_H{}^2$ which preserves the incentive constraints of the H type (and has no first order effect on the payoffs of the licensor) will make the contract of the H type less attractive to the L type because x is more valuable to the H type. Thus the licensor can always design a separating contract which will induce the L type not to invent around in the second period, and which gives the licensor the same payoffs as the contract inducing the inventing around. By definition, the former (strictly separating) contract will yield the licensor payoffs which are no higher than those provided by the optimal separating contract. It follows that the licensor would never find it more profitable to offer contracts which induce inventing around. This concludes the proof of Lemma 1.

■ *Proof of Lemma 2*

Note from (A2) that together the incentive constraints of the two types imply that every separating equilibrium contract satisfies $kV((\theta_H), \theta_H) - kV(x(\theta_H), \theta_L) \geq V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L)$. Using (8), it is clear that this condition would not be satisfied for $k < k^*$.

■ *Proof of Lemma 3*

The analysis in this case is considerably simplified by the fact that the amount of tacit know-how transferred is the same for *all* separating contracts. This in turn follows from the observation in the text that the continuation game in the second period *in equilibrium* is the same for all separating contracts and is identical to the

accrue to the L type. Allowing this would amount to *de facto* separation where the L type withdraws completely from the negotiations.

[2] If the H type were to do so, she would never invent around in the second period, and therefore, it would be as if the likelihood of having an L type were in fact higher than p.

continuation game in the symmetric information case. The reason is that once the types are revealed, the negotiations over the provision of know-how and the compensation to the licensor proceed independently of the first period.

To prove *(i)* of Lemma 3, one looks first for a equilibrium where the two types separate. The licensor's maximization program is similar to (A2) with one very important difference: $x(\theta_i)$ is no longer a control variable (and hence, neither is T_i^2). Formally, the program is

$$\underset{T_H^1,\, T_L^1}{Max}\ p_H[T_H^1 - C(x(\theta_H))] + (1-p_H)[T_L^2 - C(x(\theta_L))]$$

s.t.

$$(ia)\quad L(x(\theta_H), \theta_H) - T_H^1 \geq V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L) + L(x(\theta_L), \theta_L) - T_L^1 \qquad \ldots(A3)$$

$$(ib)\quad L(x(\theta_L), \theta_L) - T_L^1 \geq L(x(\theta_H), \theta_L) - T_H^1$$

$$(iia)\quad L(x(\theta_H), \theta_H) - T_H^1 \geq 0$$

$$(iib)\quad L(x(\theta_L), \theta_L) - T_L^1 \geq 0$$

Again, the participation constraint (rationality constraint) of the L type will bind in equilibrium and that of the H type will not, because $x(\theta_H) > x(\theta_L)$. One can therefore see that one can always find a separating contract *iff*

$$L(x(\theta_H), \theta_H) - L(x(\theta_H), \theta_L) \geq V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L). \qquad \ldots(A4)$$

From *(A3)*, we get that

$$T_L^1 = L(x(\theta_L), \theta_L)$$

$$T_H^1 = L(x(\theta_H), \theta_H) - [V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L)] \qquad \ldots(A5)$$

The "buy-in"nature of the equilibrium separating contract is easy to see from *(ib)* in (A1) whereby $T_H^1 - T_L^1 \geq L(x(\theta_L), \theta_H) - L(x(\theta_L), \theta_L) > 0$, where the second (strict) inequality follows from the condition $L_\theta > 0$. One can also see that the H type gets rents to her private information, given by $V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L)$, which is increasing in $x(\theta_L)$ since $V_{x\theta} > 0$.

The proof of *(ii)* of Lemma 3 is as follows: If separation is not feasible, then the optimal course of action open to the licensor, given that he must respect the incentive and rationality constraints of the L type, is to offer the contract $\{x^*(\theta_L), T^1(\theta_L), T^2(\theta_L)\}$, as defined by (4) and (5) in the text. This is the best that he can do with the L type, and he has no way of distinguishing between the two types. As a result, the H type obtains rents equal to $V(x^*(\theta_L), \theta_H) - V(x^*(\theta_L), \theta_L)$, which are identical to the "information rents"received under the separating contract. From the view-point of the licensor, a pooling contract is identical to an optimal separating contract with the probability, p, of $\theta = \theta_H$ equal to 0. Hence if separation were feasible, the licensor would always offer a separating contract.

■ *Proof of Lemma 4*

The condition for separation can be written as

$$k[V(x(\theta_H), \theta_H) - V(x(\theta_H), \theta_L)] \geq V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L). \quad \ldots(A6)$$

$$\text{Define } f(k) = \frac{V(x(\theta_L), \theta_H) - V(x(\theta_L), \theta_L)}{V(x(\theta_H), \theta_H) - V(x(\theta_H), \theta_L)}.$$

The continuity assumptions as well as the assumption of an interior solution imply that $x(\theta_i)$ are continuous in k, and hence, that the $f(k)$ is continuous in k. It is also true that $1 \geq f(k) \geq 0, f(0) > 0$. It therefore follows that there exists some interval $[0, k^{**})$ such that for all k in that interval, $f(k) > k$. From the definition of $f(k)$, it is clear that separation is feasible if and only if $k \geq f(k)$. Note that k^{**} is different from k^* because $x(\theta)$ is different between (7) and (9).

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