Shirking, Shelving, and Sharing Risk: The Role of University License Contracts[*]

Marie Thursby[†]
Georgia Institute of Technology and NBER

Jerry Thursby
Emory University

Emmanuel Dechenaux
Purdue University

May 17, 2004

Abstract

University license contracts are more complex than the simple fixed fees and royalties typically examined by economists. Milestones, annual payments, and consulting are prevalent. We argue that these contracts are complex because of multiple distortions present when embryonic inventions are licensed. We construct theoretical models to show that moral hazard, adverse selection, and risk aversion all play a role. Milestone payments can address inventor moral hazard without the inefficiency inherent in royalties. Royalties are optimal only when the licensee is risk averse. The potential for a licensee to shelve inventions is an adverse selection problem which can be addressed by annual fees if shelving is unintentional, but milestones are needed if the firm licensed the invention with the intent of shelving it. The effectiveness of contracts in preventing shelving depends on the credibility of the threat to take the license back from a shelving firm. This supports the intuition behind the Bayh-Dole march-in provision to take back inventions not being developed.

We test the models' predictions with survey data. The data support the finding that milestone payments help both to address inventor moral hazard and to share risk. Royalties are not used to address moral hazard and the risk sharing role of royalties is mitigated by difficulties in defining them for early stage inventions. We find that consulting is related to inventor moral hazard. Finally, our data support the use of annual payments for unintentional shelving.

---

[*] We thank Ajay Agrawal, Irwin Feller, Yann Meniere, and participants of workshops at Emory University, the NBER Higher Education Meeting, the International Industrial Organization Conference, and the Georgia Tech Roundtable for Research on Engineering Entrepreneurship for comments. We gratefully acknowledge financial support from the Alan and Mildred Peterson Foundation through the Purdue University Technology Transfer Initiative. Thursby and Thursby acknowledge support from the National Science Foundation (SES0094573).

[†] Order of authors is reverse alphabetical.

1 Introduction

University-industry technology transfer is an important part of the national innovation system and one fraught with incentive problems, largely because of the embryonic nature of university inventions. Recent research shows that the overwhelming majority of inventions licensed cannot be commercialized without further development, which often requires inventor involvement as well as business investment (Jensen and Thursby 2001, Thursby and Thursby 2003). Incentive problems on the business side are well known and the basis for the Bayh Dole Act of 1980, which gave universities the right to patent and exclusively license results from federally funded research. Framers of the Act argued that without strong property rights businesses would not invest in risky development of embryonic inventions. By including “march-in” rights so that the government can take ownership of inventions not being developed, they also recognized that firms might license inventions but ”shelve” them either because their intent in licensing was simply to prevent rivals from developing them or, more innocently, because by the time they complete technical development expected profits are less than originally anticipated. In either case, there is an adverse selection problem to the extent that potential licensees have private information on their commercialization effort. On the inventor side, the need for collaboration in development presents a moral hazard problem to the extent that university faculty prefer research to development.

In this paper, we focus on the role of contracts, and, in particular, forms of payment in overcoming these problems. Our analysis is based on the results of a survey we conducted of 113 businesses that licensed-in university inventions from 1993-1997 in which we explored the types of inventions licensed, the need for inventor cooperation in development, and the importance of contract types for various kinds of inventions. This survey, as well as our earlier survey of 62 universities, shows that the majority of contracts involve a complex mixture of payment types beyond simple fixed fees and royalties, which have been the focus of the licensing literature. For example, in our earlier survey of 62 universities, 92% reported that upfront fees were included in license contracts either “almost always” or “often,” 89% reported the same for annual payments, 97% for running royalties, and 72% for milestone payments (Jensen and Thursby 2001, Thursby *et al.* 2001). Respondents to the business survey indicated that they use consulting contracts 58% of the time when inventor collaboration is needed for development.

We construct a series of theoretical models that allow us to examine the role of contract terms in solving the moral hazard and adverse selection problems that arise when inventions need further development for commercial use. We show that a variety of payment types can address these problems. While earlier work showed that royalties can address inventor moral hazard, in our models state-contingent fixed fees or milestones serve this function without the inefficiency of royalties (Jensen and Thursby 2001, Macho-Stadler *et al.* 1996 and Choi 2001). Moreover, when milestones are available, royalties are optimal only when the licensee is risk averse (as in Caves *et al.* 1983 and Bousquet *et al.* 1998). We also show that a consulting contract through which the firm’s and the inventor’s efforts become observable to each other may increase not only the firm's and the inventor's expected payoff, but the university's as well. Thus, universities have an incentive to let the licensing firm and the inventor communicate through consulting.

In our model of unintentional shelving, we show that annual fees may be effective at solving the problem. However their effectiveness depends crucially on the credibility of the university's threat to take the license back from a shelving firm and license the technology to a different firm. The same can be said of milestones in solving the intentional shelving problem. These results support the *intuition* behind the Bayh-Dole march-in provision concerning the importance of taking back inventions that are not being developed. However, they also suggest that the need for the federal government to exercise march-in rights may be obviated by the types of contracts that are executed.

The multiplicity of payment types and distortions raises a number of empirical issues. For example, to what extent do we observe royalties for the purpose of risk sharing and milestones to assure inventor and firm development? To what extent are parties to license agreements concerned about risk, moral hazard, and adverse selection in drafting contract terms? To examine these issues we exploit data from both our business and university surveys. Our empirical results suggest that milestones are the instrument targeted toward moral hazard with respect to inventor effort. They also suggest that potential shelving motivates contract terms such as annual payments and milestones. Finally, we find a positive relationship between the use of consulting and firm concerns about moral hazard.

This paper contributes to the extensive theoretical literature on licensing which has focused primarily on fixed fees and royalties, with little attention paid to milestones (see Kamien 1992 for a review). An exception is Arora (1995), which examines the possibility of state-contingent fixed fees to solve the double hold-up problem where the licensee needs to transfer tacit knowledge and the licensor has incentives to renege once the knowledge is transferred and invent around the invention. Bousquet *et al.* (1998) also note that while such payments could replace royalties in risk-sharing, they are of limited practical importance because they require that the state of nature be observable to all parties. Thus for inventions that require no further development, milestones would not be feasible. The case of university inventions, which typically require further development, is quite different in that milestones are not difficult to define while royalties are often impossible to define upfront.[1] In this case, milestones serve to share risk. Perhaps the most striking result is that, in our setting milestones can also be used to address the intentional shelving problem while royalties exaggerate the problem. This result is in sharp contrast to previous studies of asymmetric information in which royalties can be used to overcome asymmetries in knowledge of the value of an invention (see Gallini and Wright 1990 and Beggs 1992). The difference in results arises from the source of asymmetry here being the potential for the licensee to shelve, which has not been previously examined in the context of licensing.

---

[1] Milestones are often as simple as the licensee having a business plan. Other milestones include development benchmarks such as clinical trials.

We also contribute to the empirical licensing literature which has, like the theoretical literature focused primarily on fixed fees and royalties (Taylor and Silberston 1973, Caves *et al.* 1983, Rostoker 1983, Macho-Stadler *et al.* 1996, Bousquet *et al.* 1998). With the exception of Arora (2001), Anand and Khanna (2000), and Elfenbein (2004), few studies provide econometric models.[2] The study closest to ours is Elfenbein's which examines the role of state-contingent fees, such as milestones and royalties, in the likelihood that firms licensing Harvard inventions will terminate their licenses. He finds that for large firms such fees tend to lower the hazard of termination but he finds no such effect for small firms. His analysis differs from ours in that he does not examine the role of different distortions in explaining the use of royalties and milestones.

Finally, we contribute to the growing literature on university licensing and associated public policy concerns (see Agrawal 2001 and Thursby and Thursby 2003 for reviews). The fact that the federal government has never exercised its march-in rights under Bayh-Dole has contributed to the view that perhaps these rights should be strengthened (Rai and Eisenberg 2003). Our results suggest that contract terms and a willingness of universities to terminate licenses may well provide a market mechanism to minimize distortions from shelving.

2 License contracts and moral hazard

In this section, we consider the problem faced by a university technology transfer office (TTO) that has the responsibility for licensing an invention that requires further development before commercialization. There are two stages of development. In the first, inventor effort and firm investment are needed to determine technical success, and in the second, the firm invests in commercialization. The probability of technical success is given by $p(e, X)$ where e is inventor effort and X is the firm's investment in technical development. We assume $p(0, X) = p(e, 0) = 0$ and $p(e, X) \in [0, 1)$. $p(e, X)$ is increasing in both arguments and strictly concave in e. If the invention is a technical success, the firm then invests in commercialization with probability of success $q \leq 1$. In general, we assume that inventor effort and firm investment are not contractible.

The TTO acts in the university's interest and maximizes its expected utility given by $E\mathbf{U}_A(\tilde{R}; L)$, where $\tilde{R}$ is the random total revenue from licensing equal to R_s in case of commercial success and R_f in case of commercial failure. In our university survey, we found that most respondents viewed their job as implementing Bayh Dole and viewed successful commercialization as an important objective in

---

[2] Arora examines the complementarity of know how transferred and patent rights for import agreements in India from 1950-75, but does not examine license payment terms. Anand and Khanna examine license contracts from a data base of strategic alliances with at least one US participant from 1990-93. The characteristics they examine include exclusivity, cross-licensing, ex ante versus ex post transfer, and prior relationships of licensors and licensees.

addition to revenue generation (Thursby et al. 2001). Accordingly we assume:

$$\mathbf{U}_A(\tilde{R};L) = \begin{cases} U_A((1-\alpha)R_s) & \text{if commercial success,} \\ U_A((1-\alpha)R_f) - L & \text{if commercial failure.} \end{cases}$$

where $(1-\alpha)$ is the share of revenue that accrues to the TTO and L is the loss associated with failure to commercialize. Thus even if $R_s = R_f$, the TTO strictly prefers the outcome where the invention is commercialized. We assume that U_A is continuous, twice differentiable and concave.

The inventor has von Neuman-Morgenstern utility $U_I(\alpha\tilde{R})$, where α is the inventor's share of license revenue, and incurs disutility $V(e)$ for effort level e. We assume that U_I (V) is continuous, twice differentiable and $U_I'' \leq 0$ $(V'' \geq 0)$, with a strict inequality for at least one of the two functions.

The firm's full expected payoff is $EU_F(P)$ where P is the firm's (random) profit net of license payments where U_F is continuous, twice differentiable and concave. In most of the analysis, we assume that the firm is risk neutral in which case its payoff is simply the expectation of profits minus licensing fees.

The timing of the game is as follows. The TTO offers the firm an exclusive-license contract which specifies all payment terms. If the firm rejects the offer, the game ends. If it accepts, the inventor and the firm choose their effort and investment, respectively, to determine technical success of the invention. If the invention fails for technical reasons, the game ends. If it succeeds, the firm then invests in commercial development. Payments to the TTO and the inventor may occur at any one of these stages.

2.1 Contractible effort, risk neutral firm

As a benchmark, consider the TTO's problem if inventor effort is contractible. In this case, the TTO can offer an enforceable contract specifying the amount of effort expected from the inventor. The optimal payment by the licensee is a fixed fee that extracts all of the firm's profits (Kamien 1972) given by $f^* = p(e)(q\pi(x) - C) - X \geq 0$ where $\pi(x)$ is operating profits as a function of output and C is investment in commercialization. The TTO's problem is then to choose effort to maximize its utility subject to the firm's and the inventor's participation constraints.

$$\begin{array}{cl} \text{Maximize} & \mathbf{U}_A(f;L) \\ \text{with respect to} & e \geq 0 \\ \text{subject to} & EU_I - V(e) \geq 0 \\ \text{and} & f = f^* \geq 0. \end{array} \tag{1}$$

Since f^* and $\mathbf{U}_A(f^*;L) = U_A(f^*) - (1-p(e))L$ are strictly increasing in e, the TTO will set effort at the maximum level of effort consistent with the inventor's participation. That is, if effort is contractible, the TTO will set $e = e^*$ where e^* is given by:

$$e^* = \max\{e \geq 0 | U_I(\alpha f^*) - V(e) = 0\}.$$

Under our concavity assumptions, e^* exists and is unique. Moreover, we assume that e^* is strictly positive. Note that if for effort level e^*, f^* is negative, then the firm will not accept any contract offered by the TTO because the expected profit from developing and commercializing is less than the cost of technical development at the maximum level of effort consistent with the inventor's participation. Thus, we assume that when $e = e^*$, $f^* \geq 0$.

2.2 Non-contractible inventor effort and milestones

The problem is that the inventor is subject to moral hazard since her effort is unobservable. Indeed, our university survey revealed that TTO personnel uniformly viewed obtaining faculty participation in the license process as one of the more challenging parts of their jobs (Thursby *et al.* 2001, Jensen *et al.* 2003). Jensen and Thursby (2001) show that a fixed fee has no effect on inventor effort for risk neutral inventors and that inventor effort is decreasing in the fee for risk averse inventors. They show that obtaining inventor effort requires some type of payment tied to commercial success, such as royalties or equity. In their model, there is a single development stage so there is no role for milestone payments. In this section, we show that for inventions with well defined development milestones, a payment contingent on technical success, can solve the problem of inventor moral hazard.

Formally, the inventor solves:

$$\text{Maximize } E[U_I(\alpha\tilde{R})|e] - V(e) \text{ with respect to } e. \tag{2}$$

It is clear that the expected utility term will not depend on e if the reward $\alpha\tilde{R}$ is the same whether technical success occurs or not, i.e. $E[U_I(\alpha\tilde{R})|e] = EU_I(\alpha\tilde{R})$. We therefore consider a contract which includes a payment contingent on technical success, m, in addition to the fixed fee. The firm's expected profit is:[3]

$$EU_F = p(e)(q\pi(x) - m - C) - X - f. \tag{3}$$

Assuming that the inventor behaves optimally, the TTO solves:

$$\begin{array}{cl} \text{Maximize} & E\mathbf{U}_A(\tilde{R}; L) \\ \text{with respect to} & m, f \geq 0 \\ \text{subject to} & EU_I - V(e) \geq 0,\ e = e^{**}(m, f) \\ \text{and} & EU_F \geq 0, \end{array} \tag{4}$$

---

[3] Note that even if the milestone payment is large enough that it induces the inventor to exert a positive level of effort, given the complementarity of the inventor's effort and the firm's investment, there exists another equilibrium in the technical development subgame in which the firm does not invest and the inventor spends no effort so that the project fails with probability one.Thus, if when it is offered the contract, the firm expects that such an equilibrium will prevail in the technical development subgame, it will turn down any contract with a strictly positive fixed fee. However, as in Jensen and Thursby's (2001) analysis of moral hazard with royalties and sponsored research, it is straightforward to show that with standard assumptions on the firm and inventor's problem that the no development equilibrium is unstable. We therefore assume that if the firm accepts the TTO's offer and the milestone payment provides sufficient incentives for strictly positive effort $e > 0$, the firm and the inventor coordinate on the Pareto superior equilibrium in which development occurs with probability $p(e)$.

where $e^{**}(m, f)$ is given implicitly by:

$$\begin{aligned} p'(e^{**})\{U_I[\alpha(m+f)] - U_I(\alpha f)\} - V'(e^{**}) &\leq 0, \\ e^{**}\{p'(e^{**})\{U_I[\alpha(m+f)] - U_I(\alpha f)\} - V'(e^{**})\} &= 0, \end{aligned} \tag{5}$$

and $\tilde{R} = m + f$ with probability $p(e)$ and $\tilde{R} = f$ with probability $1 - p(e)$. We assume that there exist $m \geq 0$ and $f \geq 0$ such that the firm's participation constraint is satisfied when effort is given by e^{**}. Note that a corner solution where $f = 0$ is possible. Note that the second order condition to (**??**) is satisfied and the solution is unique given our strict concavity assumption on the probability of success and the convexity of the disutility of effort. Later on, in the section where the firm has private information, we will refer to the contract solving (**??**) when the firm is risk neutral as the second best contract $\{m^{**}, f^{**}\}$. We will then assume that such a contract exists so that it satisfies $m^{**} > 0$ and $f^{**} \geq 0$.

Comparative statics allow us to show that inventor effort is increasing in the inventor's share of revenue α if she is risk neutral or not too risk averse, a result consistent with empirical studies of inventor response to economic incentives (Goldfarb and Colyvas 2003, Lach and Schankerman 2003). Optimal effort is increasing in the milestone payment, for any given individually rational α, regardless of the inventor's risk aversion or lack thereof. Finally, as in Jensen and Thursby (2001), effort is independent of the fixed fee f if the inventor is risk neutral or and decreasing in the fee if the inventor is risk aversed.

These results have three important implications when one or more parties is risk neutral. First, if the inventor and the firm are risk neutral, the TTO's payoff is strictly increasing in the fixed fee since inventor effort does not depend on f. In this case, regardless of it's attitude toward risk, the TTO will extract all of the firm's rent. Second, if in addition the TTO is risk neutral, its payoff is strictly increasing in m after substituting for the firm's rent in place of f. Hence, if all parties are risk neutral, the TTO optimally sets the milestone payment equal to the maximum amount consistent with the firm's participation, i.e.:

$$m^{rn} = \max\{m \geq 0 | p(e^{**}(m^{rn}, f^{rn}))[q\pi(x) - C - m] - X = 0\}.$$

and the fixed fee is set equal to zero, $f^{rn} = 0$. Finally, if the firm is risk neutral, it is clear that for some parameter values, the TTO could enforce the first best level of effort with the appropriate combination of m and f. It suffices to pick m and f such that $e^{**}(m, f) = e^*$. As long as the firm's participation constraint is satisfied, this level of effort is feasible. If, however, the TTO is risk averse, this level of effort is likely to be suboptimal because the payments made to the TTO are different in two different states: technical success $(m + f)$ and technical failure (f), yielding a riskier project in terms of revenue.

2.3 Non-contractible effort and royalties

How does a milestone payment compare with a royalty? Consider first the case where the firm is risk neutral and the TTO and inventor are either risk neutral or not too risk averse, so that the only use of a royalty is to induce inventor effort. Jensen and Thursby (2001) show that inventor effort is increasing in the royalty rate if royalty revenue is increasing in the rate. One could find a royalty that induces the same effort as the milestone, but the royalty introduces an output distortion that the milestone does not. For the same reason that an equity contract in Jensen and Thursby dominates a royalty contract, the milestone dominates a royalty when the royalty reduces the firm's equilibrium profits. To see this, recall that if the inventor is risk neutral (or not too risk averse), we know that, other things equal, the TTO's utility is increasing in the fixed fee in equilibrium (Jensen and Thursby, Theorem 2). Then the TTO sets $f = EU_F$. Let the royalty rate be given by r. Let $x(r)$ denote the firm's profit maximizing level of output when when the royalty rate is r. We assume that $x(r)$ is unique and $x'(r) < 0$, as is natural. Assume royalty revenue $rx(r)$ is strictly concave so that its maximum is unique. Then the firm's expected profit is $p(e)[q(\pi(x(r)) - rx(r)) - m - C] - X - f$. By setting a milestone payment equal to $m' \equiv qrx((r)) + m$, all else equal, the TTO weakly increases its payoff (strictly, if it is risk averse). It also earns additional revenue by increasing output, and thereby, increasing the fixed fee.

The question then is why empirically so many contracts include royalties and milestone payments. Not surprisingly, risk aversion provides an explanation. When the firm is risk averse, however, royalties can serve a risk sharing function as well. In our simple model, the worst state of nature for the firm is the one in which technical success occurs, but commercial success fails to be realized. In this case the firm will typically have to pay the fixed fee as well as the milestone payment, but does not have any revenue.Thus, firm risk aversion may imply that the optimal contract contains a royalty in order to reduce the variance in the distribution of profits across states from the firm's point of view. To see this consider the TTO's problem when fees, milestones, and royalties are allowed:

$$\begin{array}{cl} \text{Maximize} & E\mathbf{U}_A(\tilde{R}(r,m,f); L) \\ \text{with respect to} & r, m, f \geq 0 \\ \text{subject to} & EU_I - V(e) \geq 0,\ e = e^{**'}(r,m,f) \\ \text{and} & EU_F[P(r,m,f); e] \geq 0. \end{array} \tag{6}$$

Continue to assume the inventor is not too risk averse, so that the TTO's utility is increasing in the fixed fee. Then the TTO will use the fixed fee to extract all rents from the firm. We are then left with a problem similar to that in Bousquet *et a*l. (1998) with the exception that we allow milestone payments. Suppose that the TTO sets $(0, m, f)$, that is $r = 0$ and consider a marginal increase in r and decrease in m that keep the inventor's incentives (and hence effort) constant (i.e., $x(0)qdr = -dm$.) If q is low, this will increase the firm's expected payoff (i.e., $p(e)[(1-q)U_F'(-m - X - C - f) - qU_F'(\pi[x(0)] - m - X - C - f)] > 0$, since U_F is concave), so that the TTO can increase the fixed fee, thereby increasing its own payoff. In this case, royalty, milestone and fixed fee may coexist.[4] Proposition

---

[4] The results are ambiguous when the TTO's payoff is not increasing in the fixed fee. One

1 summarizes the optimal contract when effort is non-contractible but the only incentive problems arise from uncertainty and the need for inventor effort.

Proposition 1 *Assume that the TTO's payoff increases with the fixed fee. Under the assumptions of the model, the optimal licensing contract with unobservable inventor effort includes a royalty only if the firm is risk averse. If the firm is risk neutral, the optimal contract contains no royalty, but a positive milestone payment made upon technical success.*

2.4 Consulting

The remaining question with regard to moral hazard is the role of consulting contracts. In this section, we analyze incentives for the firm and inventor to agree on a consulting contract after the firm has accepted the TTO's contract but before they start to work on technical development. We do not model the offer process by which the inventor and the firm determine the terms of the consulting contract, but rather, we study the conditions under which both parties have an incentive to engage in consulting. We assume that consulting makes effort observable to the firm and that the consulting contract is enforceable.[5]

To analyze the incentives for consulting, note that after the firm has accepted the contract and paid the fixed fee, its continuation expected payoff before the inventor spends any effort is given by:

$$p(e^{**})[q\pi(x) - m^{**} - C] - X \geq 0.$$

It is clear that the above expression is strictly increasing in the effort level (unless $X = 0$ and $p(e^{**})[q\pi(x) - m^{**} - C] = 0$). Let e satisfy $e > e^{**}$ and define $c(e) > 0$ in the following way:

$$c(e) = (p(e) - p(e^{**}))[q\pi(x) - m^{**} - C]. \tag{7}$$

Suppose the firm were to offer a contract to the inventor such that the inventor obtains a fraction of $c(e)$ if the she spends an amount of effort e instead of e^{**}, where $e > e^{**}$. The inventor will accept some share of $c(e)$ only if:

$$\begin{aligned} p(e)U_I(\alpha(m^{**} + f^{**}) + c(e)) + (1 - p(e))U_I(\alpha f^{**} + c(e)) - V(e) > \\ p(e^{**})U_I(\alpha(m^{**} + f^{**})) + (1 - p(e^{**}))U_I(\alpha f^{**}) - V(e^{**}). \end{aligned} \tag{8}$$

which, if the inventor is risk neutral is equivalent to

$$c(e) = (p(e) - p(e^{**}))[q\pi(x) - m^{**} - C] > V(e) - V(e^{**}). \tag{9}$$

---

cannot simply argue that the TTO will seek to increase the firm's payoff to extract higher rents by increasing the fixed fee. Therefore it might not be beneficial to increase the royalty in the first place.

[5] Note that in reality, the contract may not be enforceable in court. However most consulting relationships between a licensing firm and an inventor are not one-shot as in our model. In this case, enforceability may still occur through the potential loss in reputation from shirking.

That is, the increase in the firm's expected profit must more than compensate for the extra effort.

In general, given $\{m^{**}, f^{**}\}$, from (**??**), the maximum increase in surplus or "gains from trade" from a consulting contract is achieved by maximizing $c(e)$ (indeed, $p(e)$) with respect to e subject to (**??**). It is is clear that if given $\{m^{**}, f^{**}\}$, there exists a feasible consulting contract, the TTO maximizes its profit by letting the firm and the inventor agree on the consulting contract since it increases the probability of success above $p(e^{**})$ without affecting the TTO's contract terms. Thus, if we allow for consulting and there exists $e > e^{**}$ satisfying (**??**), consulting must be part of the equilibrium since it increases all three players' payoff.

(**??**) provides insight into how consulting relates to the characterisitcs of the license. (**??**) is the relevant feasibility constraint when the inventor is risk neutral, but the qualitative observation below also holds when the inventor is risk averse (by considering (**??**)). Given the concavity of $p(e)$ and the convexity of $V(e)$, (**??**) is more likely to be satisfied when e^{**} is low. Thus, in our model, the milestone payment and consulting are complements because they are used to induce inventor effort.

3 Contracts with adverse selection

3.1 Unintentional shelving, milestones and annual fees

University licensing contracts often include fixed annual payments in addition to the fixed upfront fee. In this section, we examine the effect of a change in the firm's incentives to continue working on commercial development once technical success has occured. In this setting in which the expected value of the invention to the firm changes over time, our analysis shows that the TTO may include annual fees to prevent firms with ex-post low probabilities of continuation from holding on to the license.

Suppose that there are two types of firms, G and B. For ease of notation, we assume $q = 1$ in this section. We also let $\pi(x) \equiv \pi$. We model a firm's incentive to work on commercialization in the following way. After technical success, a firm of type i continues to work towards commercialization with probability q_i, $i = G, B$, where $q_G > q_B$. The probability that a firm is of type B is $s < 1$. The complementary probability $1-q_i$ can be interpreted as the probability that a firm of type i will decide that the project is not worth pursuing anymore once the invention works. One example of such a setting is as follows. Suppose that with probability $1 - q_i$, the firm can allocate the cost of commercial effort, C, to a different project yielding a certain net profit π^i, where $\pi^i > \pi$. In this case, the return to developing the invention is π but the full opportunity cost is $-C - \pi^i$.[6] Thus profit is negative so that the firm will choose not to incur C and will abandon the project to work on its best alternative instead. A firm's type is unknown to all players until technical

---

[6] Alternatively, $1 - p_i$ may represent the probability that the best alternative yields a payoff greater than $\pi(x) - C$, i.e., $1 - p_i = 1 - G_i(\pi(x) - C)$, where π^i is drawn from a distribution G_i.

development occurs. Upon successful technical development, the firm, and only the firm, learns its type. Since, $\pi - C > 0$, $q_i(\pi - C) \geq 0$, $i = B, G$, so that both types of firms have an incentive to keep the license after a technical success. Note that what may be thought of as strict "unintentional shelving" arises as a special case when $q_B = 0$, that is, when the firm abandons commercialization with probability one.

Central to the model, we assume that at any stage but the commercialization stage, the TTO can take the license back and search for another firm that it finds with probability z at a cost K. For simplicity, we assume that the cost of search is a constant, K, and that the TTO can only search once. If by spending K it cannot find another firm that will accept the contract, the project is abandoned.

Since at the end of the development stage the TTO can observe whether the invention works, as in the previous section it can define a state contingent fixed fee or milestone payment. If the invention does not work, either because it failed or from lack of effort, the TTO can terminate the license and take back the invention. The TTO can then go through the search process described above to try to find another firm.

For simplicity, we assume that firms and the inventor are risk neutral. The results extend directly to low levels of inventor risk aversion as long as the TTO's payoff increases with the fixed fee. If the inventor is sufficiently risk averse that the TTO's payoff decreases with the fixed fee, we postulate that the main insights derived in this section regarding the role of the milestone payment, the annual fee and the fixed fee should carry through since the results rely mostly on the effect of these instruments on the firms' payoffs. For this reason, the case of risk averse firms is more difficult to analyze as risk-sharing concerns arise.

We first characterize the optimal contract in the class of contracts that do not deter firms of any type from keeping the license after a technical success. Then, we show that if the chances of finding another firm that will work on the invention are sufficiently high, the TTO can increase its payoff by offering a separating contract.

A Pooling Contract

Suppose that the TTO's contract is such that both types of firms keep the license after a technical success. Conditional on the firm investing at the technical development stage, in this case, inventor effort is given by $e^p(m)$ (written e^p for conciseness), which solves:

$$\text{Maximize } \alpha p(e)m + f - V(e). \tag{10}$$

It can be shown that e^p is strictly concave as a function of m if the inventor is risk neutral and $V'''(e) \geq 0$.

The constraints that ensure both firms' participation at every stage are given below. The firm's expected profit (before it knows its type) must be nonnegative for it to accept the contract:

$$p(e^p(m))[(sq_B + (1-s)q_G)(\pi - C) - m] - X - f \geq 0. \tag{11}$$

We assume that the firm is obligated to pay m in the event of a technical success even if the net expected return from the invention is negative at this point. The firm therefore treats m as sunk when it decides whether or not to work on commercialization.

¿From the strict concavity of e^p in m, it follows that the left-hand side of (**??**) is single-peaked as a function of m. Assume $V'''(e) \geq 0$. Define $\hat{m}$ as the maximum solution in m to:

$$p(e^p(m))[(sq_B + (1-s)q_G)(\pi - C) - m] - X = 0. \tag{12}$$

The TTO's expected payoff from a pooling contract $\{m, f\}$ in which f is set so that (**??**) is binding is thus:

$$p(e^p)U_A((1-\alpha)(m+f)) + (1-p(e^p))U_A((1-\alpha)f) - (1-p(e^p)(sq_B + (1-s)q_G))L. \tag{13}$$

We can show that it then follows that the TTO's expected payoff function (**??**) is strictly concave as well. Moreover, (**??**) is single-peaked if the TTO is sufficiently risk averse. If the TTO is risk neutral, (**??**) is strictly increasing in m. Therefore, in the latter case, the TTO will set the highest milestone payment satisfying (**??**) in equilibrium. Denote the solution to the maximization of (**??**) with respect to m subject to (**??**) when effort is given by (**??**) by $\{m^p, f^p\}$. We have the following straightforward result.

Lemma 1 *If the TTO is risk neutral,* $m^p = \hat{m}$ *and* $f^p = 0$*.*

Separating Contract and Annual Fees

Suppose that the TTO offers a contract such that only a firm of type G will want to continue once it has found out what its type is and paid m. We call such a contract a *separating contract.* If a success occurs, but the firm decides to return the license to the TTO, the TTO may search for a second firm. Conditional on a firm of type B returning the license if a technical success occurs, the TTO maximizes his payoff by offering a fixed fee contract $\{f_2\}$. Thus in equilibrium f_2 is set equal to the firm's expected rent.[7] We assume that if a firm exists, it is of type G. Therefore, the TTO sets

$$f_2 = q_G(\pi - C), \tag{14}$$

and obtains a continuation expected payoff equal to:

$$zU_A((1-\alpha)q_G(\pi - C) - K) - (1 - zq_G)L. \tag{15}$$

Search is optimal for the TTO if

$$zU_A((1-\alpha)f_2 - K) + (1-z)U_A(-K) - (1 - zq_G)L \geq -L.$$

---

[7] Note that at this stage, the second firm knows its type if it can "examine" the technology prior to accepting the contract. Therefore there is an adverse selection problem. If firms cannot examine the technology, then they ignore their type and the TTO can offer a fixed fee equal to $(sq_B + (1-s)q_G)\pi - C$.

which definitely holds if the TTO is risk neutral and $z(1-\alpha)f_2 > K$. A risk neutral TTO finds it optimal to search if and only if:

$$(1-\alpha)zq_G(\pi - C) + zq_G L \geq K.$$

or

$$z \geq \tilde{z} \equiv \frac{K}{(1-\alpha)q_G(\pi - C) + q_G L}.$$

Unless otherwise mentioned, we will assume that L is large enough that $\tilde{z} < 1$.

The only way for the TTO to deter firms with low probabilities of continuation to keep the license is to set a fee to be paid after the first milestone. Let this fee be m_2 and denote the usual milestone payment by m_1. Optimal inventor effort in this case is denoted by $e^s(m_1, m_2)$ and solves the inventor's problem. The inventor expects to receive m_2 only if the first firm finds out that it is of type G. However every type of firm pays m_1. The inventor's problem is:

$$\text{Maximize } p(e)\alpha[m_1 + (1-s)m_2 + szf_2] + f - V(e). \tag{16}$$

As before, to ensure participation, the firm must obtain more than zero from accepting the contract before it finds out what its type is (given that effort is e^s). However, recall that only firms of type G continue and pay m_2 after development. Thus the constraint is:

$$p(e^s)[(1-s)(q_G(\pi - C) - m_2) - m_1] - X - f \geq 0, \tag{17}$$

Since the TTO wants to induce a firm of type B to return the license in case of success, m_2 must also satisfy:

$$q_B(\pi - C) - m_2 \leq 0, \tag{18}$$

or:

$$m_2 \geq q_B(\pi - C). \tag{19}$$

But if (**??**) holds, then it is clear that a firm of type G wishes to continue in case of a technical success, that is:

$$m_2 < q_G(\pi - C). \tag{20}$$

If the TTO finds its optimal to search after a success has occurred, the TTO's expected payoff from a separating contract is:

$$\begin{aligned} p(e^s)[(1-s)U_A((1-\alpha)(m_1+m_2+f)) &+ sU_A((1-\alpha)(m_1+f)) \\ +szU_A((1-\alpha)f_2 - K) &+ s(1-z)U_A(-K)] \\ +(1-p(e^s))U_A((1-\alpha)f) &- (1-p(e^s)q_G(1-s(1-z))L. \end{aligned} \tag{21}$$

The first two terms multiplied by $p(e^s)$ represent the sum of the utilities obtained from a technically successful invention in case the first firm is a type G (probability $1-s$) and in case the first firm is a type B (probability s). The second two terms multiplied by $p(e^s)$ represent the sum of the utilities obtained assuming that the TTO decided two search upon taking the license back from a firm of type L. The term multiplied by $1-p(e^s)$ is simply the utility obtained from the first firm's fixed fee in case of a technical failure. Finally, the probability of commercial success is $(1-s)p(e^s)q_G$ (first firm) plus $szp(e^s)q_G$ (second firm, conditional on the first firm being a type B). The overall probability of failure is then 1 minus the sum of the two probabilities and simplifies to the expression in (**??**).

Since the TTO will extract all rents from the first firm, it will set the fixed fee f^s such that (**??**) is binding. Moreover, if the TTO is risk neutral, (**??**) writes:

$$p(e^s)[(1-\alpha)(m_1+(1-s)m_2+szf_2)-sK]+(1-\alpha)f^s-[1-p(e^s)q_G(1-s(1-z))]L,$$

which, after substituting for f^s, is strictly increasing in both m_1 and m_2. If z is sufficiently high, and s and K are sufficiently low, a separating contract exists when the TTO is risk neutral. Lemma 2 and Proposition 2 below characterize a sufficient condition on the parameters for a separating contract to exist and improve upon the pooling contract.

Lemma 2 *There exists $\hat{z} < 1$ such that if $z \geq \hat{z}$, $((1-s)q_B + szq_G)(\pi - C) \geq \hat{m}$.*

Proof. It follows from the fact that since $X > 0$, (**??**) implies

$$\hat{m} < (1-s)q_B + sq_G)(\pi - C).$$

The rest of the proof is straightforward. Q.E.D.

In Proposition 2 below, we use the following assumption.

A1 $q_B(\pi - C) \leq \hat{m}$.

A1 states that a type B's expected profit from commercializing is lower than the maximum milestone the TTO can ever set for (**??**) to hold. If **A1** holds, then a firm of type B obtains a negative ex-post expected payoff. However, its payoff from continuing towards commercialization is strictly positive after it has paid m.

Proposition 2 *Assume **A1**. If the TTO is risk neutral, then*

(i) If $z \geq \max\left\{\frac{q_B}{q_G}, \tilde{z}, \hat{z}\right\}$, a separating contract including an annual fee m_2 above $q_B(\pi - C)$ exists and is optimal.

(ii) If $z < \tilde{z}$, a pooling contract without annual fee exists and is optimal.

Proof. See Appendix.

Proposition 2 above describes two extreme cases. In the first case, upon technical success, the probability z that a second firm exists and is a good match for the technology is high. The fact that a separating contract is optimal in this case is fairly straightforward to show. On the other hand, if $z < \tilde{z}$, the TTO's utility from incurring the cost of search for a second firm is negative. Therefore, a separating contract is clearly not optimal in this case.

In a one period model, Beggs (1992) also shows that if the difference between types is sufficient, an uninformed licensor will offer a separating contract that only high-value informed licensees accept. Out timing assumptions allow us to relate this result to the presence of annual fees (rather than high fixed fees) in most university license contracts.

3.2 Intentional shelving

In this section, we incorporate the possibility that firms might license the invention simply to block rivals from developing it. This is similar to the situation of "sleeping patents" examined by Gilbert and Newbery (1982) in which case a monopolist patents substitutes for its product to keep others from producing it. Well known examples include DuPont's patenting of 200 substitutes for Nylon. More recently, Cohen et al. (2000) find that when firms in their survey patent their inventions, 82% (64%) patent them in order to block rivals in the case of product (process) inventions. As noted earlier, the licensing literature has ignored this possibility, but the language of Bayh Dole and our interviews with TTO personnel suggest shelving is a realistic possibility.

Suppose that a firm has expressed interest in the invention. With probability s the firm is interested in licensing the invention to prevent development (either by itself or a rival). It is natural to think of this motive arising either when the firm is producing a close substitute for the invention or working to develop a substitute. This firm, which we call a *shelver*, S, earns profit π^m when it obtains the license for the innovation but does not commercialize it, and $\pi^c < \pi^m$, if it obtains the license and commercializes it. Moreover, the shelver earns profit π^d if another firm, holding the exclusive license, commercializes the invention. A shelver therefore saves an amount $D \equiv \pi^m - \pi^d$ when it obtains the license, thereby preventing a firm from commercializing the innovation. On the other hand, with probability $1 - s$, the firm is not a shelver. We say that such a firm is a *non-shelver*, NS. Non-shelvers earn "monopoly" profits equal to $\pi(x)$ by optimally producing x units of the new product if they commercialize it; they gain nothing from licensing and shelving. In this model, shelvers have an incentive to hold on to the license to prevent another firm from developing the product.

The timing of the game is as follows. Nature picks a first firm to which the TTO offers a contract. The firm accepts or rejects the contract. If it rejects, the TTO must then decide whether or not to search for a second firm at a cost K. We assume that there exists a second firm that is a non-shelver with probability z. If the firm accepts, the firm and the inventor play the simultaneous development game. If the outcome of the development game is a failure, the TTO takes the license back from the firm. Note that a failure can occur because either the firm did not invest or the inventor spent no effort, or simply because the invention does not work. Moreover, after the realization of the outcome, we assume that the inventor can observe whether or not the firm invested. This may be because there exists a consulting contract between the inventor and the firm, or more naturally because of required cooperation between the inventor and the firm. We assume that the inventor can then decide whether or not to report to the TTO about the firm's investment, after which the TTO decides whether or not to search for a second firm at a cost K. Again, we assume that there exists a non-shelver with probability z. If a second firm is found, the TTO offers a contract and the firm accepts or rejects it. We make the assumptions that the TTO can only search once and that successful search cannot occur after the commercialization stage. Therefore, a shelver that could hold on to the license until the commercialization stage obtains π^m.

When all parties are risk neutral and under the critical assumption that the inventor can observe whether or not the firm invested X (but not the type of the firm), we show that if expected milestone revenue in the second best contract $\{m^{**}, f^{**}\}$ is sufficiently high and a condition on the profit levels obtained by the various types of firms is satisfied, the second best contract can be supported in a Perfect Bayesian Equilibrium.

A2 $\pi(x) + \pi^d - C > \pi^m - zD.$

Proposition 3 *If both **A2** and* $p(e^{**})m^{**} \geq \max\left\{\frac{K-zp(e^{**})qL}{(1-\alpha)z}, \frac{V(e^{**})}{(1-z)\alpha}\right\}$ *hold, then the second best contract* $\{m^{**}, f^{**}\}$ *can be supported in a Perfect Bayesian equilibrium in which shelvers do not accept the TTO's contract, but non-shelvers do.*

Proof. See Appendix.

The result in Proposition 3 depends crucially on the assumption that the inventor can observe whether or not the firm worked at the development stage. If this is not the case, even if assumption **A2** is satisfied, the TTO may not be able to prevent shelvers from accepting the contract. Moreover, because for a wide range of parameter values, inventor effort is not continuous in the milestone payment, a complete analysis is somewhat tedious.

More interestingly, note that annual fees are not required to drive shelvers out in Proposition 3. A priori, there is no reason to think that annual fees should be effective at preventing intentional shelving since a shelver has a strong incentive to keep the licensed technology. In Proposition 3, the elements required for the result to go through is the TTO's ability to credibly commit to taking the license back and searching for another firm in case of failure.

4 Empirical implications

Table 1 summarizes our theoretical results where a plus indicates that a payment type works to overcome the distortion in the column heading. Consider first the issues of risk and inventor moral hazard. Both royalties and milestone payments

	Risk	Moral Hazard	Unintentional Shelving	Intentional Shelving
Fixed fees				
Upfront		0/-		
Annual			+	
Milestone	+	+		+
Royalty	+	+	-	-
Consulting		+		+

Table 1: Theoretical results

work to overcome the moral hazard problem and provide a mechanism to share risk. The problem with the use of milestones to share risk is that as long as $q < 1$, they do not share the risk associated with commercialization. When royalties and milestones are both allowed in a contract, the optimal contract specifies a positive royalty only when the firm is risk-averse. Since milestones and royalties are both common in license agreements, an interesting empirical issue is whether we can distinguish the reasons for their use.

Which instruments work to overcome the adverse selection problem depends on whether shelving is intentional or not. The only general result is that regardless of the intent royalties are inappropriate. Fixed fees paid annually provide a mechanism to deter unintentional shelving while the same milestone contract that is optimal in the case of moral hazard allows the TTO to separate intentional shelvers from nonshelvers. In our models, fixed fees paid upfront play no role other than to allow the university to extract all of the licensee's rent.[8] Finally, consulting contracts by which the firm's and the inventor's efforts become observable to each other can increase not only the firm's and the inventor's expected payoff, but the university's as well so that universities have an incentive to let the licensing firm and the inventor communicate through consulting.

As other authors have noted, empirically testing license theories is problematic because of the information problems that give rise to the distortions of interest. Existing studies have relied on survey evidence, and we do as well. A portion of our data come from our earlier survey of the TTOs of 62 US universities, which was designed to provide information on the types of inventions licensed, their objectives in licensing, and their licensing practices. As discussed in Jensen and Thursby (2001), this survey shows that typical contracts include a mixture of payment types. The data that allow us to examine the extent to which different payment types are related to risk sharing or moral hazard come from a survey of businesses who license from universities. Details of survey design for both surveys are given in Appendix C.

---

[8] As in Jensen and Thursby (2001) fixed fees paid upfront either have no effect on inventor effort or make the moral hazard problem worse. If we were to model intentional shelving where the inventor cannot observe firm effort, then upfront fees could play a role.

4.1 Risk and moral hazard with royalties and milestones

Proposition 1 implies that license contracts for risky inventions requiring inventor collaboration should include milestone payments designed to obtain inventor effort and royalties to share risk when the licensee is risk averse. We know from our university survey that inventions licensed in early stages, such as proof of concept or lab scale prototype, are riskier from a technical standpoint than are later stage technologies, for which manufacturing cost is known or those ready for commercialization. University TTO personnel indicated that because of the early stage of development, upfront fees were difficult to include in contracts, noting unknown market potential as an important factor. According to both surveys, three fourths of the inventions licensed are no more than a lab scale prototype. Respondents to the business survey indicated that roughly half of the inventions they licensed-in from universities failed and that 46% of those that failed did so for technical reasons. Both surveys suggest that risk is a factor considered in the execution of license agreements, and that *ceteris paribus* earlier stage inventions are considered riskier than late stage.

To provide information on business attitudes toward risk and payment types, we asked respondents the importance of different payment types for early stage technologies and late stage technologies. To provide information on business attitudes toward inventor cooperation, we asked the importance of different payment types when faculty input is critical and when it is not critical. The exact questions are given in Table 2. Immediately below each question respondents were asked to indicate using a 5 point Likert scale from 5 (extremely important) to 1 (not important) the importance of several payment types including running royalties, milestone payments and equity. Thus, for each of the four questions in Table 2 we have the importance attached to each of three payment types. That is, each respondent can provide up to 12 answers: the importance of each of three payments types for each of four technology characteristics. Out of 112 respondents to the survey, 91 answered at least some of the questions (58% provided at least one answer to each question). Not all of the 91 respondents noted the importance of each of the payment types.[9] Overall, running royalties are always more important than the other payment types, this is followed by milestone payments and then equity. The average given by respondents regarding the importance of running royalties is 3.7 while importance for milestones and equity is 2.9, and 1.7, respectively.

To uncover the relative importance of various payment types under the circumstances outlined in the questions in Table 2, we consider three regressions in which the dependent variable is the importance a respondent attaches to a particular payment type (running royalties, milestone payments, equity) as a function of a set of dummy variables that capture characteristics of the technology (early stage,

---

[9] It is not surprising that many respondents left blank answers for some questions. For example, if a firm has never used faculty in further development, then they would be unable to answer questions regarding the importance of payment types when faculty are critical and when faculty are not critical.

late stage, faculty critical, faculty not critical). That is, we estimate the equations

$$R_{ip} = \beta_0 + \beta_1 EARLY_{ip} + \beta_3 CRIT_{ip} + \beta_4 NOTCRIT_{ip} + \varepsilon_{ip},\ i = 1, ..., n,\ p = 1, ..., 3$$

R_{ip} is the importance attached by individual i to payment type p, $EARLY_{ip} = 1$ for a technology that is early stage (0 otherwise), $CRIT_{ip} = 1$ for a technology for which faculty input is critical (0 otherwise), and $NOTCRIT_{ip} = 1$ when faculty input is not critical (0 otherwise). The omitted category is late stage technologies. Notice that these equations take a particular payment type (e.g., running royalties) and then consider responses across the four questions listed in Table 2.

Since the responses are ordinal from 5, extremely important, to 1, not important, we use an ordered probit estimator. With each respondent appearing in each equation up to four times (that is, we have a panel of data) we use fixed effects models. Finally, we use robust standard errors. Regression results for payment type are in Table 3. Part A presents the probit coefficients along with t statistics and an indication of the level of significance. Part B provides chi-square statistics in tests for equality of the coefficients given in Part A.

The milestones equation gives very clear results: milestones are most important when faculty are critical, this is followed by early stage inventions, then late stage inventions (the omitted category) and faculty not critical are not significantly different. The importance of milestones when faculty are critical supports our argument that milestones can serve to mitigate the moral hazard problem. The finding that early stage inventions are next most important likely stems from the use of milestones to share risk and the fact that early stage inventions are generally riskier than late stage inventions.

In the equation for running royalties we find several clear results. First, we find that there is no significant difference in responses for the cases where faculty are critical and faculty are not critical. No difference here indicates that running royalties are not used to solve the moral hazard problem. If they were important for the moral hazard problem, then running royalties would be more important when faculty are critical.

Second, running royalties are more important for late stage than for early stage technologies. While this may seem counter to our theory which emphasized the role of running royalties in risk sharing, it is important to note the following issue. Respondents to our university survey noted that running royalties are hardest to define for early stage inventions.[10] Many university inventions are so embryonic that downstream products cannot be defined at the time of license and many can serve as the basis for a variety of applications (Shane 2001). Thus, in contrast

---

[10] One of the university survey questions specifically asked about the use of running royalties and reasons for universities including it in licenses. One third of the 52 respondents indicated that running royalties were always or almost always used except for software or technologies for internal firm use only. The second most common response made by 8 respondents (15.4%) concerned the difficulty of establishing the commercial value or market characteristics of an invention. Three respondents indicated they were an important component in dealing with risk. As one respondent said "... if we knew how much the invention was going to make for the licensee - in advance - it would be quite reasonable to ask all royalties be paid up front."

to the presumption of Bousquet *et al* (1998) that milestones may be hard to define, in the case of university licenses royalty definition can be even more difficult. There are therefore two competing effects for royalties: risk sharing which *ceteris paribus* would be more important for early stage technologies, and the difficulty of determining royalty rates which would make them more important for late stage technologies (which still reflect market risk). The result here suggest that the latter effect dominates.

Finally, the equity equation reveals nothing. This might well follow from the fact that for large, publicly traded companies, equity and cash are essentially equivalent. We considered this regression after dropping large firms, but the results continued to be poor.

4.2 Adverse selection and contract terms

Propositions 2 and 3 provide the conditions under which payment terms can separate shelvers from non-shelvers. The problem with testing these propositions is that if such separating contracts exist, then, in practice, shelving would not occur. Further, given the Bayh-Dole "march in" clause, it is difficult to believe that either TTO or businesses would accurately report problems with shelving. Nonetheless, the data we have indirectly support the models in Section 4.

In our business survey, we asked respondents how often they licensed in inventions for a variety of reasons. Reasons included product development, research tools, process improvement, and preventing a rival company from licensing the technology. Only 7 percent indicated that blocking a rival was an important reason. This is somewhat interesting since in Cohen et al.'s (2000) survey of R&D labs, the overwhelming reason for patent inventions was blocking rivals. Note, however, that blocking a rival need not involve shelving as the licensee could develop the invention and commercialize it to block their rivals.

Several questions in the university survey indicate that TTO personnel consciously attempt to prevent shelving. While we did not ask about milestone payments or fixed fees directly, we asked about the usefulness of annual payments in lieu of running royalties.[11] Not surprisingly, the most common response to this question had to do with technologies for which it is hard to track a sales record (for example, when the technology is used for internal firm purposes). However, 10 of the 54 respondents (18.5%) who answered this question volunteered that annual fees were used to ensure due diligence to prevent shelving. In many cases, the respondents were clearly concerned about unintentional shelving. Several responses specifically noted intentional shelving, however, with one respondent noting the use of annual fees because of "fear that companies are only licensing technology to 'shelve' it due to a competitive market."

Despite the caveat that we would expect underreporting, we asked TTO respondents if they had problems with shelving despite their best attempts at due

---

[11] Specifically, we asked the open ended question "In what circumstance is it desirable to include annual license fees in a license agreement instead of running royalties?"

diligence.[12] Eleven of 61 (18%) respondents indicated that they had had problems with firms licensing a technology with the intention of shelving. Interestingly, none of the 10 who volunteered that annual fees were used to ensure due diligence indicated that they had problems with shelving. This is evidence, *albeit* weak, that upfront fees, annual fees and milestone payments can serve to deter those who initially intend to shelve.

Finally, we asked for reasons that universities have had for terminating contracts.[13] Thirty-six of the 46 respondents (78%) to this question noted due diligence problems and/or non-payment. Only one university said they had never terminated a contract. The federal government has never exercised its march-in rights under Bayh-Dole, and it has been suggested that this is a shortcoming of the Act (Rai and Eisenberg 2003). Contract terms and a willingness of universities to terminate licenses may well make moot the issue about whether the federal government should be involved in this action.

4.3 Moral hazard and consulting

In Section 3 we considered conditions under which the firm and inventor have incentives to agree on a consulting arrangement. In this section we examine data from our industry survey on the use of consulting to obtain faculty input into further development of licensed technologies.

In our survey of industry licensing executives we asked respondents to indicate the percent of time faculty consulting was used when faculty input was critical for further development. On average, respondents indicated that they used consulting 58.7% of the time. There is, however, a lot of variation in responses. The standard deviation was 34% and the range was from 0% to 100%. Some of this variation, we argue, is a function of the seriousness of the moral hazard problem faced by firms. The measure we use for moral hazard is the importance firms attach to milestone payments when faculty are critical to further development. We saw earlier that milestone payments are a mechanism for dealing with the moral hazard problem so we claim that the importance attached to milestone payments is a measure of the moral hazard faced by a firm.

We regress the response made to our question concerning consulting to the importance attached to milestone payments when faculty are critical ($MILESTONE\_IMPORT$). Recall that respondents provide measures of importance ranging from 5 (extremely important) to 1 (not important). In this analysis we do not use the actual responses since respondents likely define levels of importance differently – for example, two respondents might view some payment type for some technology as equally important, but one scores it as a "5" while the other scores it as a "4." To get around this problem we compute the measure of

---

[12] Our question was "Have you had problems with companies despite proper due diligence terms acquiring a technology and shelving it to prevent its commercialization?"

[13] Our question was "When the university has terminated an agreement, what was the most common reason?"

importance as the deviation of a response from the average response a respondent makes.[14]

Additional regressors include a dummy variable for small firms ($SMALL$). Here we define small as firms with fewer than 100 employees. Our reason for including a measure for size is based on discussions with university technology transfer professionals who tell us that it is more common for small firms to use consulting as a means for obtaining faculty input.

We also include a variable to measure distance of a firm from the universities from whom they license ($DISTANCE$). In our survey we asked for the five universities most important in terms of licensing. Our measure of distance is the average distance from the universities listed by each respondent.

The use of consulting may depend, in part, on the stage of development of the technology. To control for stage of development we include the percent of the time that the firm licenses in technologies that are only a proof of concept ($PROOF$) and the percent of time that they license in technologies for which there is only a lab scale prototype ($PROTOTYPE$). These are the two earliest stages for technologies.

Finally, firms can choose between sponsored research and consulting as means of obtaining faculty input. In our survey we not only asked about the percent of time that consulting was used but also the percent of time sponsored research was used when faculty are critical. The average response was 46.8% of the time for sponsored research. Our final variable is the percent of time sponsored research is used ($SPONRESEARCH$). Note that sponsored research and consulting, while not mutually exclusive, are very likely to be simultaneously determined. For that reason we use two-stage least squares. The instrument for sponsored research is the percent of in-house research conducted by the firm that is basic research. In Thursby and Thursby (2003) we find a significant and positive relationship between sponsored research and in-house basic research.

Results are in Table 4. The method is two stage least squares and we report robust standard erros. Due to missing observations we have only 36 observations. Nonetheless, we are able to uncover some significant relationships. Not surprisingly, the greater the distance between the firm and universities the less likely are consulting arrangements. Small firms, as expected, are more likely to use consulting. Finally, the coefficient of the importance attached to milestone payments when faculty are critical is positive and significant. This result supports our theoretical result that consulting is a mechanism for solving the moral hazard problem.

We do not find the use of sponsored research to be related to consulting, nor do we find the stage of development to be significant. Since the t statistic for $PROOF$ is very small we dropped it from the regression. Results are in the second panel of Table 4. All coefficients are significant at a 10% or lower level. In particular, we continue to find that consulting is a mechanism for solving the moral hazard problem.

---

[14] We do not need to make this adjustment for the econometric models considered earlier since we used a fixed effects model.

5 Conclusion

University-industry technology transfer is an important part of the national innovation system and one fraught with incentive problems, largely because of the informational asymmetries and investment needed for industrial application of many university inventions. In this paper, we focus on the role of contracts, and in particular the form of payment in overcoming these distortions and argue that commonly observed license contracts can be explained by the presence of multiple distortions. We show that in the presence of moral hazard and adverse selection, contracts with simple fixed fees and royalties are unlikely to be optimal. Both our theoretical and empirical results suggest that milestones are prevalent because of inventor moral hazard. Royalties are not used to address moral hazard and the risk sharing role of royalties is mitigated by difficulties in defining them for early stage inventions. They also suggest that consulting as a part of license contracts is related to inventor moral hazard. Our results on adverse selection support the use of annual payments for unintentional shelving and milestones for intentional shelving. However their effectiveness depends crucially on the credibility of the university's threat to take the license back from a shelving firm and license the technology to a different firm. These results support the *intuition* behind the Bayh-Dole march-in provision concerning the importance of taking back inventions that are not being developed. However, they also suggest that the need for the federal government to exercise march-in rights may be obviated by the types of contracts that are executed.

References

[1] Agrawal, Ajay. "Research on University to Industry Knowledge Transfer: Literature Review and Unanswered Questions," *International Journal of Management Reviews,* December 2001, 3, pp.*285-302.*

[2] Agrawal, Ajay and Garlappi, Lorenzo. "Public Sector Science and the Strategy of the Commons," 2003, mimeo, Queens University.

[3] Anand, Bharat and Khanna, Tarun. "The Structure of Licensing Contracts," *The Journal of Industrial Economics, 2000, 48,* pp.*103-135.*

[4] Arora, Ashish. "Licensing Tacit Knowledge: Intellectrual Poperty Rights and the Market for Know-How," *Economics of innovation and new technology*, 1995, 4, pp. 41-59.

[5] Arora, Ashish, Fosfuri, Andrea, and Gambardella, Alfonso. *Markets for Technology: The Economics of Innovation and Corporate Strategy.* Cambridge, MA: MIT Press, 2001.

[6] Beggs, Alan W. "The Licensing of Patents under Asymmetric Information." International Journal of Industrial Organization, 1992, (10), pp. 171-191.

[7] Bousquet, Alain, Cremer, Helmuth, Ivaldi, Marc, and Wolkowiz, Michel. “Risk Sharing in Licensing.” *International Journal of Industrial Organization,* 1998, 16, pp. 535-554.

[8] Caves, Richard E., Crookell, Harold and Killing, J. Peter. “The Imperfect Market for Technology Licenses.” *Oxford Bulletin of Economics and Statistics*, 1983, (45), pp. 249-268.

[9] Choi,J.P. ”Technology Transfer with Moral Hazard,” *International Journal of Industrial Organization*, 2001, 19, pp. 249-266.

[10] Cohen, Wesley, Nelson, Richard, and Walsh, John. “Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not),” 2000, NBER Working Paper No. w7552.

[11] Elfenbein, Dan. “Contract Structure and Performance of Technology Transfer Agreements: Evidence from University Licenses,” mimeo, 2004.

[12] Feldman, Maryann, Feller, Irwin, Bercovitz, Janet, and Burton, Richard, “Equity and the Technology Transfer Strategies of American Research Universities,” *Management Science,* 48 (1), January 2002, pp. 105-121.

[13] Gallini, Nancy. “Deterrence by Market Sharing: A Strategic Incentive for Licensing,” *American Economic Review* ,1984, 74, pp. 931-41.

[14] Gallini, Nancy T. and Wright, Brian D. “Technology Transfer under Asymmetric Information.” *RAND Journal of Economics*, 1990, (21), pp. 147-160.

[15] Gilbert, Richard J. and Newbery, David M.G., “Preemptive Patenting and the Persistence of Monopoly,” *American Economic Review,* 1982, 72(3), pp. 514-526.

[16] Goldfarb, Brent, and Colyvas, Jeannette, “Do Strong Property Rights Inspire Academic Entrepreneurship,” September 2003, mimeo.

[17] Hounshell, D. H. and Smith, J.K., *Science and Corporate Strategy.* Cambridge: Cambridge University Press, 1988.

[18] Jensen, Richard and Thursby, Marie C., “Proofs and Prototypes for Sale: The Licensing of University Inventions,” *American Economic Review*, March 2001, 91(1), pp. 240-259.

[19] Jensen, Richard, Thursby, Jerry G., and Thursby, Marie C., “The Disclosure and Licensing of University Inventions: The best we can do with the s**t we get to work with,” *The International Journal of Industrial Organization*, November 2003, 21(9), pp. 1271-1300.

[20] Kamien, Morton I. ”Patent Licensing.” in Robert Aumann and Sergiu Hart, *Handbook of Game Theory,* 1992, Amsterdam: North Holland.

[21] Katz, Michael and Shapiro, Carl, "On the Licensing of Innovations." *Rand Journal of Economics, 1985, 16,* pp. *504-520.*

[22] Lim, Tek-Ang, and Veugelers, Reinhilde, "On Equity as a Payment Device in Technology Licensing with Moral Hazard," 2003, mimeo.

[23] Macho-Stadler, Martinez-Giralt, and Castrillo, Perez. "The Role of Information in Licensing Contract Design." Research Policy, 1996, (25), pp. 43-57.

[24] Rai, Arti K. and Eisenberg, Rebecca S., "Bayh-Dole Reform and the Progress of Biomedicine," *Law and Contemporary Problems,* Winter/Spring 2003, 66, pp. 288-313.

[25] Rostoker, M.D., "A Survey of Corporate Licensing," *The Journal of Law and Technology, 1983,* 24, pp.pp. 59-92.

[26] Shapiro, Carl, "Patent Licensing and R&D Rivalry," *American Economic Review, 1985,* 75, pp. 25-30.

[27] Taylor, C. T. and Silberston, Z. A., *The Economic Impact of the Patent System: A Study of the British Experience.* Cambridge: Cambridge University Press, 1973.

[28] Thursby, Jerry, Jensen, Richard, and Thursby, Marie, "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities," *Journal of Technology Transfer*, 2001, 26, 59-72.

[29] Thursby, Jerry and Thursby, Marie, "Who is Selling the Ivory Tower? Sources of Growth in University Licensing," *Management Science,* 2002, 48(1), pp. 90-104.

[30] Thursby, Jerry and Thursby, Marie, "University Licensing and the Bayh-Dole Act," *Science*, August 22, 2003, 301, p. 1052.

[31] Thursby, Jerry and Thursby, Marie, "Are Faculty Critical? Their Role in University Licensing," *Contemporary Economic Policy,* 2003, forthcoming.

[32] Wang, X. Henry, "Fee Versus Royalty Licensing in a Cournot Duopoly Model," *Economics Letters*, July 1998, 60(1), pp. 55-62.

6 Appendix A: Proof of Proposition 2

We begin the proof of Proposition 2 with (ii) since it is straightforward. ¿From the definition of $\tilde{z}$, if $z < \tilde{z}$, the TTO never finds it optimal to search. Thus, there is nothing to gain from forcing a type B firm to give the license back. Therefore, the TTO will offer the optimal pooling contract.

We now show that if **A1** and the conditions in (i) are satisfied, a separating contract exists and yields a greater payoff than the optimal pooling contract. First, the optimal separating contract must involve an annual payment m_2. Second, from $z \geq \tilde{z}$, the TTO finds it optimal to search if it reposses the license. The optimal contract then maximizes the TTO's expected payoff given by:

$$p(e^s)[(1-\alpha)(m_1+(1-s)m_2+szf_2)-sK]+(1-\alpha)f^s-[1-p(e^s)q_G(1-s(1-z))]L,$$

which after substituting for f^s is equivalent to:

$$(1-\alpha)p(e^s)((1-s)m_2+szf_2-sK)+(1-\alpha)p(e^s)((1-s)q_G(\pi-C)-X)-[1-p(e^s)q_G(1-s(1-z))]L,$$

subject to the constraint that $m_1 \geq 0$, $m_2 \geq 0$ and $f^s \geq 0$.

To show that there exists a feasible separating contract that improves upon the pooling contract, suppose that the TTO sets m_2 infinitesimally above $q_B(\pi - C)$ and $m_1 = 0$. The inventor solves:

$$\text{Maximize } p(e)\alpha[(1-s)q_B(\pi-C)+szq_G(\pi-C)]+f-V(e). \tag{22}$$

Since from $z \geq \hat{z}$ and Lemma 2, $(1-s)m_2+szf_2 = (1-s)q_B(\pi-C)+szq_G(\pi-C) \geq \hat{m}$.It is clear that the solution to the above is greater than $e^p(\hat{m})$. Moroever, from **A1** and by definition of $\hat{m}$,

$$p(e^p(\hat{m}))[(1-s)(q_G(\pi-C)-q_B(\pi-C))]-X > 0.$$

Thus, for every $e \geq e^p(\hat{m})$,

$$p(e)[(1-s)(q_G(\pi-C)-q_B(\pi-C))]-X > 0,$$

so that the firm's constraint holds when evaluated at the solution to (**??**). Therefore, the contract that consists in setting m_2 infinitesimally above $q_B(\pi-C)$, $m_1 = 0$ and f^s so that the expected rent is extracted from the firm is feasible and yields strictly greater revenue and effort than the pooling contract. Finally, from $z \geq \frac{q_B}{q_G}$ it follows that $[1-p(e^p)q_G(1-s(1-z))] \leq [1-p(e^p)(sq_B+(1-s)q_G)]$ so that the seperating contract thus defined clearly yields a lower probability of incurring the cost L than the pooling contract. Therefore, the pooling contract is not optimal. Q.E.D.

In Proposition 2, we have not shown that milestone payments and annual fees can coexist in the sense that both instruments are strictly positive. m_2 is consrained to be slightly above $q_B(\pi-C)$. However, since the annual fee also serves to provide incentives for the inventor to exert effort, it could be the case that $m_1 = 0$. Letting $F(m_2) \equiv ((1-s)m_2 + szf_2 - sK + q_G(\pi - C) - X)$, the derivatives of the TTO's utility with respect to m_2 and m_1 respectively write:

$$(1-\alpha)p'(e^s)\frac{\partial e}{\partial m_2}F(m_2) + (1-\alpha)(1-s)p(e^s) + \frac{\partial e}{\partial m_2}p'(e^s)q_G(1-s(1-z))L.$$

$$(1-\alpha)p'(e)\frac{\partial e}{\partial m_1}F(m_2) + \frac{\partial e}{\partial m_1}p'(e)q_G(1-s(1-z))L.$$

To determine whether $m_1 > 0$ in a seprating contract, one must evaluate the above expressions at $m_1 = 0$ and $m_2 = q_B(\pi - C)$ and compare them. If the derivative with respect to m_1 is greater than that with respect to m_2, then $m_1 > 0$. Since e^s is concave in m_1 and m_2, from (**??**), $1 - s < 1$ implies $\frac{\partial e}{\partial m_1} > \frac{\partial e}{\partial m_2}$. Thus, whether or not $m_1 > 0$ depends on the size of the term $(1-\alpha)(1-s)p(e^s)$.

7 Appendix B: Proof of Proposition 3

We show that under the assumptions in the proposition, $\{m^{**}, f^{**}\}$ can be supported in a Perfect Bayesian Equilibrium. Suppose the TTO offers $\{m^{**}, f^{**}\}$ to the first firm. We show that if beliefs are such that a) shelvers turn down the contract and b) if the inventor turns in a firm for shirking, both the TTO and the potential second firm believe the firm did not work, the contract satisfies all incentive constraints and maximizes the TTO's payoff when the other players in accordance with sequential rationality.

First, we analyze the TTO's behavior if the first firm turned down the TTO's offer. In this case, the TTO can either abandon the project, or search for another firm. If it searches and finds a firm, it is clear that it will offer $\{m^{**}, f^{**}\}$ to that firm. Thus the expected profit from seach is:

$$z(1-\alpha)p(e^{**})m^{**} - K - (1 - zp(e^{**})q)L \tag{23}$$

while the expected payoff from abandoning the project is:

$$-L. \tag{24}$$

Thus, the TTO will search if, and only if (**??**) is greater than (**??**). Rearranging, this is equivalent:

$$p(e^{**})m^{**} \geq K - zp(e^{**})qL(1-\alpha)z,$$

which holds by our assumption in the proposition.

Suppose that the first firm has accepted. At the technical development stage, the inventor chooses effort and the firm chooses its investment level. Suppose a non-shelver picks X with probability one (we check later that this is optimal). If shelvers turn down the contract in equilibrium, then, upon observing that the firm accpeted, the inventor believs that it is a non-shelver. Thus, the updated probability that the firm is a non-shelver is equal to one in this case. Therefore, the inventor maximizes:

$$\alpha p(e)m^{**} - V(e). \tag{25}$$

with respect to e. The solution to (**??**) is e^{**}.

We now examine a shelver's incentive constraints. Suppose that contrary to equilibrium behavior, a shelver entered. Under which conditions will it work? In equilibrium, the inventor turns in a firm that did not work, but doe not misreport and turn in a firm that worked, and the TTO always searches if the inventor turns a firm in. Thus, if a shelver shirks, but the inventor works at effort level e^{**}, the second firm still has a probability of success equal to $p(e^{**})$. At the technical development stage, if the shelver shirks, its expected profit is then:

$$(1-z)p(e^{**})q\pi^d + (1-(1-z)p(e^{**}))\pi^m$$

If it works, it is simply:

$$\pi^m - p(e^{**})m - X$$

Thus, a shelver that entered will work with probability $v > 0$ only if:

$$\pi^m - p(e^{**})m - X \geq (1-z)p(e^{**})q\pi^d + (1-(1-z)p(e^{**}))\pi^m$$

or

$$(1-z)p(e^{**})[qD - m] - X \geq 0. \tag{26}$$

But since $e = e^{**}$ and $m = m^{**}$, by definition:

$$p(e^{**})[q\pi(x) - m^{**} - C] - X = 0.$$

But then by assumption **A2**, it easy to see that (**??**) cannot hold.

We now check that the TTO would take the license back and license succesfully with probability z in case the inventor reported that the first firm did not work. Since the TTO offers a fixed fee contract $\{f_2\}$ that extracts all rents from the second firm, based on a probability of success $p(e^{**})$), the relevant conditions are the firm's participation constraint:

$$p(e^{**})[q\pi(x) - C] - X \geq 0 \tag{27}$$

and the TTO's incentive constraint

$$z(1-\alpha)f_2 - (1 - zp(e^{**}q)L - K \geq -L \tag{28}$$

But since $p(e^{**})[q\pi(x) - C] - X = p(e^{**})m^{**} > 0$, substituting for the latter in place of f_2, one can see that (**??**) is satisfied by the assumption in the proposition.

It remains to check that all other equilibrium conditions are satisfied. Consider the inventor's incentive constraints. At the technical development stage, after having exerted effort $e(m^{**})$, on the equilibrium path, the inventor earns the following expected payoff:

$$\alpha\alpha p(e^{**})m^{**} - V(e^{**}).$$

Suppose the inventor works, but deviates and "turns in" the firm for shikring. Since the inventor turning a firm in should not be observed in equilibrium, Bayes's rule cannot be used to compute the TTO's and the second firm's updated probability that the firm truly shirked based on the inventor's report. Suppose that the TTO and the second firm believe that the firm shirked if the inventor reports that it did. Then, the TTO will take the license back and license it again with probability z. The inventor's payoff is then:

$$\alpha z f_2 - V(e^{**}).$$

Substituting for f_2 in the above, it is easy to see that deviating yields a lower payoff than conforming since $p(e^{**})m^{**} > zf_2$.

Suppose now that the inventor sets $e = 0$ instead of $e = e^{**}$, and turns the firm in for shirking. Since in this case, the TTO believes that the inventor worked but the firm did not, it will search for another firm. Thus the iventor can obtain:

$$\alpha z f_2 = \alpha z p(e^{**})e^{**},$$

from such a deviation. Conforming to the equilibrium strategy yields:

$$\alpha p(e^{**})e^{**} - V(e^{**}).$$

Thus, it must be the case that:

$$\alpha p(e^{**})e^{**} - V(e^{**}) \geq \alpha z p(e^{**})e^{**},$$

but rearranging terms, the above holds by the assumption in the proposition.

8 Appendix C: Survey Data

Our data come from two sources. The first is a survey of university based technology transfer professionals and the second is a survey of business executives who actively license-in from universities. The university survey was sent to the top 135 U.S. universities in terms of licensing revenue as reported in the 1996 AUTM Survey and 62 responded. The majority of universities responding were public, and of the public universities responding, 62% were land-grant institutions. Private universities accounted for 37% of the responses. Average industry sponsored research for universities in the sample was $16.9 mil-lion in 1996, and federally sponsored research was $149.6 million. The average technology office in the sample reported 26.3 licenses executed, 92.3 inventions disclosures, 30.1 new patent applications and $4.2 million in income for 1996. Compared to the 131 U.S. universities who responded to the 1996 AUTM survey, the respondents to our survey represent 68% of industry sponsored research, 75% of fed-erally sponsored research, 71% of royalty income, 74% of the licenses executed, 70% of the invention disclosures and 48% of the new patent applications. Further details of the survey can be found in Jensen and Thursby (2001).

The business survey was designed to be answered by individuals actively engaged in executing licenses, options, and/or sponsored research agreements with universities between 1993-1997. We re-ceived responses from 112 business units that had licensed-in university inventions. Firms in our sample accounted for at least 15% of the license agreements and 17% of sponsored research agreements reported by AUTM in 1997. Seventy-nine firms in the sample responded to a question on the top five universities with whom they had contractual agreements. The 85 universities mentioned include 35 of the top 50 uni-versities in terms of industry sponsored research and 40 of the top 50 licensing universities in the 1997 AUTM Survey. The majority of respondents were employed by small firms, with 46% answering for firms with less than one-hundred employees and 17% for firms with more than one hundred but less than five hundred employees. In terms of industry segments, 31% of the respondents identified pharmaceuti-cals as the main industry in which their firm operated, 36% indicated biotechnology and medical devices as their main industry, and 33% indicated other industries. Ninety-one percent of the sample conducted some R&D in-house. On average, 37% of the R&D conducted in-house was basic or discovery research, 44% was development of new products, and 18% was for process improvement. Further details of the survey can be found in Thursby and Thursby (2001, 2003).

Table 2. Business Survey Questions On Importance of Payment Types

1. When you license-in an *early* stage technology (e.g., proof of concept or lab scale prototype only), how important to you is it to include the following payment types?

2. When you license-in a *late* stage technology (e.g., nearly ready for commercial use)), how important to you is it to include the following payment types?

3. When faculty input *is* critical for further development of a technology, how important is it that the license-in agreement include the following payment types?

4. When faculty input *is not* critical for further development of a technology, how important is it that the license-in agreement include the following payment types?

Table 3. Fixed Effects Ordered Probit Results on Payment Type

A. Regression Results

	Milestone			Running Royalties			Equity	
	Coef.	t-Stat		Coef.	t-Stat		Coef.	t-Stat
EARLY	0.327	1.68	*	-0.613	-2.81	***	-0.197	-0.63
CRIT	0.929	3.62	***	-1.464	-6.19	***	0.237	0.64
NOTCRIT	-0.162	-0.85		-1.392	-6.30	***	-0.385	-1.06
No. Obs.	297			300			259	

B. Tests of Equality of Coefficients

	Milestone		Running Royalties		Equity	
Null Hypothesis	Chi-Square Stat		Chi-Square Stat		Chi-Square Stat	
EARLY=CRIT	5.97	**	16.41	***	1.80	
EARLY=NOTCRIT	7.46	***	16.84	***	0.35	
CRIT=NOTCRIT	20.07	***	0.10		2.96	*

***	Significantly different from zero at 1% level.
**	Significantly different from zero at 5% level.
*	Significantly different from zero at 10% level.

Table 4. Two-Stage Least Squares Results on Consulting

	Coef.	t-Stat	Coef.	t-Stat
SPONRESEARCH	-0.588	-1.54	-0.570	-1.88*
DISTANCE	-0.026	-2.39**	-0.026	-2.64**
MILESTONE_IMPORT	13.821	3.11***	13.745	3.29***
SMALL	19.073	1.81*	18.963	1.89*
PROOF	0.016	0.10		
PROTOTYPE	0.272	1.81	0.260	1.82*
CONSTANT	77.495	5.24***	77.988	5.85***
No. Obs.	36		36	
r-Square	0.50		0.51	

*** Significantly different from zero at 1% level.
** Significantly different from zero at 5% level.
* Significantly different from zero at 10% level.