

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

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Abstract

University license contracts are more complex than the fixed fees and royalties typically examined by economists. We show that milestones, annual payments, and consulting are common because moral hazard, risk sharing, and adverse selection all play a role when embryonic inventions are licensed. Milestones 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 licenses an invention intending to shelve it. Whether annual fees or milestones prevent shelving depends on the university credibly threatening to take the license back from a shelving firm. When such a threat is not credible an upfront fee is needed. This supports the *rationale* for Bayh-Dole march-in rights but also shows the need for the *exercise* of these rights can be obviated by contracts.

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.

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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 majority of inventions licensed cannot be commercialized without further development, which often requires inventor as well as business investment neither of which is contractible (Jensen and Thursby 2001, Thursby and Thursby 2003). 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. On the business side, incentive problems are the basis for the Bayh Dole Act of 1980, which gave universities the right to own and exclusively license results from federally funded research. Framers of the Act argued that without exclusive rights businesses would not invest in risky development of embryonic inventions. By including "march-in" rights so that the government could take back ownership of inventions, they also recognized the possibility that firms might stand in the way of commercialization. Two such instances involve firms "shelving" an invention either because their intent in licensing was simply to prevent development by their rivals or, more innocently, because by the time development is completed 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.

In this paper, we focus on the role of contracts 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 in the context of the contingent ownership scheme specified by Bayh-Dole and examine the role of contracts in solving the moral hazard, risk-sharing, and adverse selection problems that arise when inventions need further development for commercial use. 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). When parties are risk neutral and the inventor can observe the firm's effort, however,

there are instances in which the same milestone contract that solves the problem of inventor moral hazard can prevent intentional shelvers (firms which never intend to develop an invention) from licensing. This result depends on the ability of the university to credibly threaten to take the license back from a shelving firm and license the technology to a different firm. When licensee effort is neither contractible nor observable, a high upfront fee is more effective at separating shelvers from non-shelvers than is the threat to take the license back.

Milestone contracts are also not sufficient to solve the shelving problem when firms expect to commercialize an invention *ex ante*, but face different incentives once development is completed. In this case, we show that annual payments in addition to a milestone are needed to provide the firm with the incentive to return the invention to the university. Here again, the ability of contracts to separate shelving from nonshelving firms depends on a credible commitment on the part of the university to terminate the license. Thus while our analysis supports the *rationale* for the Bayh-Dole march-in provision it also suggests that the need for the federal government *to exercise* these rights may be obviated by the types of contracts that are executed.

Finally, we 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.

The multiplicity of payment types and distortions raise 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, rather than royalties, 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 simple contracts involving fixed fees and royalties, with little attention paid to milestones (see Kamien, 1992, for a review). Exceptions are Arora (1995) and Bousquet *et al.* (1998) which examine the role of milestones in the transfer of tacit knowledge and risk sharing, respectively. By largely ignoring issues related to licensing of inventions that require further development, this literature is unable to explain the complications that arise in university licensing. Thus, for example, in Bousquet *et al.*'s (1998) analysis, milestones are considered impractical for risk sharing since there are no development milestones when the state of nature can be observed. The case of inventions requiring further development is quite different in that milestones are not as difficult to define as royalties, in which case

milestones can serve to share risk.¹ Perhaps the most striking result is that, in our setting milestones can 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. Our analysis of shelving also provides an argument for upfront fees in addition to the usual argument of rent extraction. In our case, we show that a fixed fee upfront can be useful in separating shelvees from nonshelvees.

Our work is also related to the literature on the organization of R&D with incomplete contracts. The work closest to ours is that of Aghion and Tirole (1994a, b) which examines conditions under which an invention should be owned by the research unit, final customer, or some combination. They derive conditions under which ownership is irrelevant for efficiency. One condition is when the invention could be developed independently by the research unit or the customer. The types of inventions that we model are those which cannot be independently developed by either the university inventor or the firm. Moreover, in their model the final customer has no incentive to prevent development of the invention. We contribute to this literature by showing that contingent ownership combined with appropriate contract terms is important when shelving is a possibility.

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 2004 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

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

²Arora 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.

provide a market mechanism to minimize distortions from shelving.

Section 2 provides a benchmark model of university licensing in which inventor effort and firm investment are both contractible. Sections 3 and 4 examine contract terms when inventor effort and firm investment are not contractible, respectively. Section 5 presents empirical evidence on contract design and Section 6 concludes.

2 A model of university licensing

Consider the problem faced by a university technology transfer office (TTO) that has the responsibility for licensing an invention requiring 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. We assume $p(0, X) = p(e, 0) = 0$ and $p(e, X) \in [0, 1)$ and 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 $q \leq 1$.

The university owns and can exclusively license the invention, but in accordance with Bayh-Dole, this property right is contingent on the licensee making "reasonable" efforts to commercialize it. The TTO acts on behalf of the university and maximizes utility given by $EU_A(\tilde{R}; L)$, where \tilde{R} is 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, most respondents viewed their job as implementing Bayh Dole with successful commercialization as an important objective in addition to revenue generation (Thursby *et al.* 2001).³ Accordingly we assume:

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

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.

The inventor has utility $U_I(\alpha\tilde{R})$, where α is her share of license revenue and incurs disutility of effort, $V(e)$. She is either risk neutral or risk averse, so that $U_I'' \leq 0$, and her marginal disutility of effort is strictly positive and strictly increasing ($V' > 0$ and $V'' > 0$).

The firm's full expected payoff is $EU_F(P)$ where P is the firm's (random) profit net of license payments. The firm may be risk neutral or averse. In most of the analysis, we focus on risk neutral firms, in which case, a firm investing X in Stage 1 and C in Stage 2 has expected profits gross of payments to the TTO of

$$p(e, X)(q\pi(x) - C) - X.$$

³We abstract from any agency problems between the TTO and administration. See Jensen *et al.* (2003) regarding the alignment of TTO and administration objectives.

where $\pi(x)$ denotes operating profits as a function of output. Throughout, we assume that the functions U_A , U_I and U_F are continuous and differentiable twice as a function of income. We also assume that U_A is strictly concave as a function of income.

The timing is as follows. The TTO offers the firm an exclusive-license contract that specifies all payment terms. If the firm rejects the offer, the game ends. If it accepts, the inventor and the firm choose effort and investment, respectively, to determine technical success of the invention. If the invention fails for technical reasons, it becomes worthless but the game may continue. If it succeeds, the firm then invests in commercialization.

In general inventor effort and firm investment (e , X or C) are neither observable nor contractible, but as benchmark, consider the TTO's problem if they are observable and contractible. In this case, the TTO can offer an enforceable contract specifying the amount of effort expected from the inventor and the optimal payment by the licensee is a fixed fee, f^* , that extracts all of the firm's profits (Kamien 1972). The TTO's problem is to choose effort to maximize its utility subject to the firm's and the inventor's participation constraints.

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

Since f^* and $\mathbf{U}_A(f^*; L) = U_A(f^*) - (1-p(e))L$ are strictly increasing in e , the TTO will pick 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 $e = e^*$, $f^* \geq 0$.

3 Non-contractible inventor effort

The problem is that the inventor is subject to moral hazard since her effort is unobservable. Our university survey revealed that TTO personnel uniformly view obtaining faculty participation as one of the more challenging parts of their jobs (Thursby *et al.* 2001, Jensen *et al.* 2003). Jensen and Thursby (2001) 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.

3.1 The role of milestones: Shirking

In general, the inventor solves:

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

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. 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:

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

Assuming that the inventor behaves optimally, the TTO solves:

$$\begin{aligned} &\text{Maximize} && EU_A(\tilde{R}; L) && (4) \\ &\text{with respect to} && m, f \geq 0 \\ &\text{subject to} && EU_I - V(e) \geq 0, e = e^{**}(m, f) \\ &\text{and} && EU_F \geq 0, \end{aligned}$$

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

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

Given our assumptions on the marginal disutility of effort, $e^{**}(m, f) > 0$ only if $m > 0$.⁴ The contract that induces positive inventor is then an $m > 0$ and $f \geq 0$ such that the firm's participation constraint is satisfied when effort is given by $e^{**} > 0$, which we denote as $\{m^{**}, f^{**}\}$.

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

⁴Given 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. As in Jensen and Thursby's (2001) analysis of moral hazard with royalties and sponsored research, however, it is straightforward to show that this equilibrium is unstable with standard assumptions on the firm and inventor's problem, 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 $e > 0$.

(2001), effort is independent of the fixed fee f if the inventor is risk neutral and decreasing in the fee if the inventor is risk averse.

Our results have three important implications when one or more parties is risk neutral. First, if the inventor and 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 its 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 . Thus, 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.:

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

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 by choosing 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 may 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. Thus, in general, we refer to $\{m^{**}, f^{**}\}$ as a second best contract.

3.2 The role of royalties: Shirking or sharing risk?

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 while 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). Thus the TTO will set a fixed fee f that extracts all rents from the firm. 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 then why do we observe that so many contracts include royalties and milestone payments? Not surprisingly, risk aversion provides an ex-

planation. When the firm is risk averse, 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:

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

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 al.* (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.⁵ Proposition 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.*

3.3 The role of consulting

The remaining puzzle with regard to inventor effort is why consulting is prevalent if milestones and royalties provide a solution to inventor moral hazard. 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 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.

⁵If the TTO's payoff is not increasing in the fixed fee, one cannot simply argue that the TTO will try to increase the firm's payoff to extract higher rents by increasing the fixed fee.

We assume that consulting makes inventor effort observable to the firm and that the consulting contract is enforceable.⁶

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:

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

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

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

which, if the inventor is risk neutral is equivalent to

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

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

In general, given $\{m^{**}, f^{**}\}$, from (7), 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 (8). It 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 (8), consulting must be part of the equilibrium since it increases all three players' payoff.

(9) provides insight into how consulting relates to the characteristics of the license. (9) 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 (8)). Given the concavity of $p(e)$ and the convexity of $V(e)$, (9) 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.

⁶Note 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.

4 Non-contractible firm effort

In this section, we examine the problems that arise because the firm’s commercialization effort is not contractible. We examine two cases, one in which a firm licenses with the intent to prevent rivals from commercializing the invention and another in which a firm licenses intending to commercialize the invention but decides not to commercialize it after spending time on development. In either case, the licensee may shelve the invention. In order to focus on the ability of contingent ownership and contracts to prevent shelving, we assume all parties are risk neutral.⁷ In the first case, we show that the second best contract $\{m^{**}, f^{**}\}$ can separate shelving from nonshelving firms as long as the inventor can observe firm development efforts and the university threatens to take back the invention without firm effort. If the inventor cannot observe these efforts, the threat is not credible and the existence of a separating equilibrium requires a higher upfront fee and lower milestone payment. In the second case of unintentional shelving, a milestone payment and fixed fee alone are not sufficient. An additional payment such as commonly observed annual fees is needed to deter shelving. Importantly, this equilibrium also depends on the ability of the TTO to credibly threaten to take the invention back in the absence of firm effort.

4.1 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 inventions, 82% (64%) patent them in order to block rivals in the case of product (process) inventions. While the licensing literature has ignored this possibility, our interviews with TTO personnel reveal that they think 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 firm either producing or trying to develop a substitute for the invention. The firm, which we call a *shelver*, S , earns profit π^m when it obtains the license for the invention but does not commercialize it, and $\pi^c < \pi^m$, if it obtains the license and commercializes it. The shelver earns 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,

⁷The 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.

preventing a firm from commercializing the innovation. With probability $1 - s$, the firm is a *non-shelver*, NS . Non-shelvers earn 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.

The timing of this game is as follows. Nature picks a firm to which the TTO offers a contract. The firm accepts or rejects the contract. If it rejects, the TTO must decide whether or not to search for a second firm at a cost K . We assume a second firm that is a non-shelver exists with probability z . If the first 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 could occur because the firm did not invest or the inventor spent no effort, or simply because the invention does not work. Moreover, we assume that the inventor can observe whether or not the firm invests. This may be because of 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 cost K . If it cannot find another firm that will accept the contract, the project is abandoned. With probability z the TTO finds a second firm, in which case 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 .

4.1.1 Firm effort observable by the inventor

When the inventor can observe whether or not the firm invests X (but not the firm's type), we show that the second best contract $\{m^{**}, f^{**}\}$ can be supported in a Perfect Bayesian Equilibrium if the expected milestone payment is sufficiently high and the following condition on the profits of shelving and nonshelving firms holds:

Proposition 2 *For sufficiently low K , there exists $\tilde{D}_1 > 0$ such that that if $D = \pi^m - \pi^d \leq \tilde{D}_1$ 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 conditions under which the second best contract prevents shelving are intuitive. The condition on D requires that net monopoly profits from successful commercialization are higher than the expected savings to a shelver.

Critical for the result in Proposition 2 is the TTO's ability to credibly commit to taking the license back and searching for a second firm. The condition that

ensures the TTO would do so is more likely to hold the lower the search cost, the higher the probability of finding another firm, and the greater the utility loss from a failure to commercialize. Finally, note that there is no role for royalties in driving intentional shelvers out since shelvers prefer contracts with all payments in royalties, which of course they never pay.

As we show in the next section, the result also depends crucially on the assumption that the inventor can observe whether or not the firm invests in development. If this were not the case, TTO may not be able to prevent shelvers from accepting the contract by offering the second best contract.

4.1.2 Non-observable firm effort

In many situations, the inventor will not be able to observe the firm's effort. In this case, the contract $\{m^{**}, f^{**}\}$ cannot be supported in equilibrium. For negligible cost of search K , we show that if D , the difference between monopoly and duopoly profit for a shelver, is not too large and z , the probability that a second firm interested in licensing exists is not too low, in equilibrium, the TTO offers a contract with a fixed fee above the second best level f^{**} . The fixed fee is set sufficiently high so that shelvers find it more profitable to reject the TTO's contract, but not so high that non-shelvers would also reject the contract. Thus, in equilibrium, the fixed fee is used as a mechanism to sort the firms.

If D is high, the TTO is not able to prevent shelvers from accepting the contract. This is most evident by considering the extreme case in which $D \geq q\pi - C$, where the return to a shelver from blocking commercialization is greater than the return to a non-shelver from commercializing. In this case, any individually rational fixed fee for a non-shelver can also be paid by a shelver. For D high, if an equilibrium (in pure strategies) exists, then in equilibrium, shelvers accept the contract and shirk at the development stage. The TTO may or may not find it optimal to search for a second firm after observing a failure at the development stage depending on the cost of search and the probability of finding another firm.

Proposition 3 *For K negligible, there exist \tilde{D}_2 and \tilde{z} such that if $D \leq \tilde{D}_2$ and $z \geq \tilde{z}$, there is a unique equilibrium in pure strategies. In equilibrium, $m < m^{**}$ and $f > f^{**}$. Moreover, shelvers do not accept the TTO's contract.*

Proof. See Appendix.

Thus, even with risk neutral parties, up-front fees may play a critical role in sorting shelvers from non-shelvers. Contrary to the previous section, the threat of taking the license back and search for another firm is not used to deter shelvers from accepting the contract. This is a consequence of the fact that, absent the inventor's signal that the firm did not work, the TTO cannot credibly commit to licensing to a second firm. This is because in any equilibrium in which no shelver enters, the potential second firm would interpret a failure with the first firm as sure evidence that the invention does not work. Therefore, the second firm would

not be willing to invest. On the other hand, if an equilibrium in which shelvees accept the first contract and shirk, a second firm may be willing to take on the license after observing a failure since then, there is a chance that the invention failed because the first firm shirked.

The \tilde{D}_2 threshold in the result above is always below the threshold \tilde{D}_1 in Proposition 2. Therefore, the range of shelving incentives for which a separating contract is feasible when the inventor does not observe the firm's effort is smaller than if the inventor can report to the TTO. Moreover, separation always entails a distortion of the contract terms away from second best.

4.2 The role of annual payments: Unintentional shelving

The other case we examine is one in which the firm expects to commercialize the invention *ex ante*, but faces different incentives once development is completed.⁸ In this case, the second best contract $\{m^{**}, f^{**}\}$ is no longer optimal. We consider when annual fees, which are common in contracts, can induce the firm to return an invention that it discovers has low commercial potential *ex post*.

Suppose there are two types of firms, G and B , and for simplicity let $q = 1$ and $\pi(x) \equiv \pi$. After technical success, a firm of type i invests in 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 $1 - q_i$ is the probability a firm of type i will decide the project is not worth pursuing once it knows the invention works. To illustrate, suppose 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 $-C - \pi^i$, so that the firm will abandon the project for its best alternative. A firm's type is unknown to all players until technical development occurs, at which point the firm, and only the firm, learns its type. Since, $\pi - C > 0$, $q_i(\pi - C) \geq 0$, $i = B, G$, both types of firms have an incentive to keep the license after a technical success. Strict "unintentional shelving" arises as a special case when $q_B = 0$, that is, when the firm abandons commercialization with probability one.

As before, we assume that at any point before 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 . We assume that if a second firm exists, it is of type G . Moreover, the TTO can observe if the invention works after development, so it can define a state contingent fixed fee or milestone payment.

We first characterize the optimal contract in the class of contracts that do not deter firms of either type from keeping license after technical success. We then

⁸Although the CellPro-Johns Hopkins march-in dispute involves many issues beyond those considered here, a part of the Bayh and Cutler 1997 petition is related. The invention in question was the My-10 antibody which Johns Hopkins licensed to Becton Dickinson. Becton Dickinson did invest in development but later decided to withdraw from the therapeutic business. The petition claimed that the university should have taken the license back rather than allowing Becton Dickinson to license it to Baxter.

show that if the chances of finding another firm are sufficiently high, the TTO can increase its payoff by offering a separating contract which includes an annual payment.

A. Pooling Contract

Consider a TTO contract such that both types of firms keep the license after they determine technical success. Conditional on firm investment in technical development, inventor effort is $e^p(m)$ which solves:

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

If, as we assume, the inventor is risk neutral and $V'''(e) \geq 0$, then e^p is strictly concave as a function of m .

For the firm to accept the contract before it knows its type, expected profit must be nonnegative or:

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

We assume the firm is obligated to pay m on technical success even if the net expected return from the invention is negative at this point. Thus m is sunk once the firm decides to commercialize or not.

Denote by \hat{m}' , the highest milestone payment satisfying that a firm would ever be willing to pay given that the inventor behaves optimally. This milestone payment is the maximum value of m that solves :

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

Lemma 1 characterizes the optimal pooling contract $\{m^p, f^p\}$. The proof is straightforward. The result follows primarily from the fact that given risk neutrality, the TTO's expected payoff from a pooling contract $\{m, f\}$ in which f is set to extract the firm's rent is strictly increasing in the milestone payment.

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

B. Separating Contract and Annual Fees

Now consider a *separating contract* such that only a type G firm will continue once it knows its type and has paid the milestone. Recall that conditional on a type B firm returning the license, the TTO can search for another firm. At this point, technical development has been completed so that the TTO maximizes his payoff by offering a fixed fee contract $\{f_2\}$, which in equilibrium is equal to the firm's expected profit.⁹ Therefore, the TTO sets

$$f_2 = q_G(\pi - C), \quad (13)$$

⁹Note 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 $(sq_B + (1-s)q_G)\pi - C$.

and obtains a continuation expected payoff equal to:

$$z(1 - \alpha)q_G(\pi - C) - K - (1 - zq_G)L. \quad (14)$$

The TTO will only search if it is optimal to do so. Search is optimal for the TTO if and only if this continuation payoff exceeds the loss associated with failure to commercialize. This occurs for a sufficiently high probability of finding a second firm, or

$$z \geq \tilde{z}_1 \equiv \frac{K}{(1 - \alpha)q_G(\pi - C) + q_GL}.$$

To further characterize the optimal separating contract, we make use of the following result.

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 $X > 0$, (12) implies

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

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

The only way for the TTO to induce type B firms to terminate 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 that it is type G . However every type of firm pays m_1 . Given such a contract, the inventor's problem is:

$$\text{Maximize } p(e)\alpha[m_1 + (1 - s)m_2 + szf_2] + f - V(e). \quad (15)$$

As before, to ensure participation, expected profits prior to firms finding out their type must be nonnegative (given that effort is e^s). However, recall that only firms of type G continue and pay m_2 after development. Thus the inventor's constraint is:

$$p(e^s)[(1 - s)(q_G(\pi - C) - m_2) - m_1] - X - f \geq 0, \quad (16)$$

In Proposition 3, we assume the following:

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

A1 states that a type B firm's expected profit from commercializing is lower than the maximum milestone the TTO could ever set for (11) to hold. If **A2** does not hold, then clearly, a separating contract fails to exist since to deter firms of type B , the TTO would have to set m_2 above the maximum amount a firm is willing to pay ex-ante.

Proposition 4 *Assume A1. If the TTO is risk neutral, then*

- (i) *If $z \geq \max \left\{ \frac{q_B}{q_G}, \tilde{z}_1, \hat{z} \right\}$, a separating contract including an annual fee m_2 above $q_B(\pi - C)$ exists and is optimal.*
- (ii) *If $z < \tilde{z}_1$, a pooling contract without annual fee exists and is optimal.*

Proof. See Appendix.

Proposition 3 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. On the other hand, if $z < \tilde{z}_1$, 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. Note that, as in the case of intentional shelving, the existence of such a separating contract depends on the incentives for the TTO to terminate a license and search for another firm. However, because the licensee does not know its type until after the technical development stage, the ability of the inventor to observe and report shelving is no longer important.

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. Our timing assumptions allow us to relate this result to the presence of annual fees (rather than high fixed fees) in most university license contracts.

5 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 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 problems associated with non-contractible firm effort depends on whether shelving is intentional or not, as well as the credibility of the university's threat to take back the license and license to another firm. 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 shelvees from nonshelvees if the inventor can observe the firm's development effort. In our models, fixed fees paid upfront play no role other than to allow the university to extract all of the licensee's rent unless the

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

Table 1: Theoretical results

firm’s development effort is unobservable. In this case, a sufficiently high fixed fee paid upfront can separate shelvees. 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.

5.1 Inventor shirking, risk, and contract terms

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. Both the university and business surveys reported 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. Thus 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 to them 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 to them of different payment types when faculty input is critical and when it is not critical.¹⁰ 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.¹¹ 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 examine the relative importance of payment types in 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, late stage, faculty critical, faculty not critical). That is, we estimate the equations

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

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.

¹⁰The intent here was to discern business attitudes. Thus alternative measures such as the portion of contracts with various payment types would not be useful since it is an equilibrium result and hence also reflect university attitudes and negotiation.

¹¹It 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.

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) which are not significantly different from faculty not critical. The importance of milestones when faculty are critical supports our argument that milestones 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 should be more important when faculty are critical.

Second, running royalties are more important for late stage than for early stage technologies. This somewhat counterintuitive result is most likely related to the fact that running royalties are the hardest to define for early stage inventions.¹² Many university inventions are so embryonic that downstream products cannot be defined at the time of license and many inventions have a variety of applications (Shane 2001). Thus, in contrast to Bousquet *et al's* (1998) presumption that milestones may be hard to define, in the case of university licenses, royalties may be even more difficult to define. 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 results 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.

5.2 Shelving and contract terms

Propositions 2 and 3 provide the conditions under which payment terms can separate shelvees from non-shelvees. The problem with testing these propositions is that if such separating contracts exist, then, in practice, shelving should not occur. Further, given the Bayh-Dole “march in” clause, it is difficult to believe that either

¹²One 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.”

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 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 that firms reported they patented inventions was to block 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.¹³ 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 diligence.¹⁴ Eleven of 61 (18%) respondents indicated that they 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 universities terminated contracts.¹⁵ Thirty-six of the 46 respondents (78%) to this question noted due diligence problems and/or non-payment. Only one university said it 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). Our theoretical results along with the apparent willingness of universities to terminate licenses suggests the opposite—that the march-in provision has been effective in providing the incentive for universities to execute separating contracts.

¹³Specifically, 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?”

¹⁴Our question was “Have you had problems with companies despite proper due diligence terms acquiring a technology and shelving it to prevent its commercialization?”

¹⁵Our question was “When the university has terminated an agreement, what was the most common reason?”

5.3 The role of consulting

In Section 5 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 importance as the deviation of a response from the average response a respondent makes.¹⁶

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

¹⁶We do not need to make this adjustment for the econometric models considered earlier since we used a fixed effects model.

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 errors. 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.

6 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 to deter unintentional shelving and milestones to prevent licensing by intentional shelvees. The existence of such separating contracts, however, depends crucially on the university's incentives to take back inventions. A university is more likely to take back inventions the higher is its disutility from the

failure to commercialize, the higher is the probability it can find another licensee, and the lower are its search costs.

Notice that the contracting problems we examine are predicated on the split ownership implicit in Bayh-Dole, that is, the university owns the invention but the federal government reserves the right to take it back in the absence of reasonable commercialization effort. We argue that this march-in provision provides the incentive for the university to execute separating contracts, so that in equilibrium actual march in would not occur.

It is the university ownership of the invention that makes our contracting problems fundamentally different from those of Aghion and Tirole (1994). Thus in our model the researcher (inventor) has a moral hazard problem that does not exist in their framework where either the researcher or the customer (licensee in our case) owns the invention. An interesting question for further research, particularly given increasing commercialization through inventor startup companies, is when it would be optimal for the university to transfer ownership to the inventor. This question has also been the topic of debate among a number of European countries where traditionally ownership has resided with the inventor (OECD 2003). Another question, currently a point of contention between some firms and universities, is when the firm funds the research, whether firm ownership is optimal.

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7 Appendix A: Proof of Proposition 2

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) if a firm accepts the contract, then it must be a non-shelver and b) if the inventor turns in a firm for shirking, it must indeed be the case that it shirked, the contract satisfies all incentive constraints and maximizes the TTO's payoff when the other players behave 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 search is:

$$z(1 - \alpha)p(e^{**})m^{**} - K - (1 - zp(e^{**})q)L \quad (17)$$

while the expected payoff from abandoning the project is equal to $-L$. Thus, the TTO will search if, and only if (17) is greater than $-L$. Rearranging, this is equivalent to:

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

which holds if K is sufficiently low.

Suppose now that the first firm has accepted. At the technical development stage, the inventor chooses effort and the firm chooses its investment level. Suppose for now that 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 accepted, the inventor believes 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:

$$\alpha p(e)m^{**} - V(e). \quad (18)$$

with respect to e . The solution to (18) is e^{**} .

We now examine a shelver's incentive constraints. Suppose that contrary to equilibrium behavior, a shelver entered. Under what conditions will it invest in developing the invention? In equilibrium, the inventor turns in a firm that did not invest, but does not misreport and turn in a firm that invested, 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:

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

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:

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

or

$$zp(e^{**})[qD - m] - X \geq 0. \quad (19)$$

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

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

Thus, if $q\pi(x) - C > zqD \iff D < \frac{q\pi(x)-C}{zq} (> 0)$, (19) cannot hold. Let $\tilde{D}_1 = \frac{q\pi(x)-C}{zq}$.

We now check that the TTO would take the license back and license successfully with probability z in case the inventor reported that the first firm did not work. At this stage, since the risk neutral TTO believes that the inventor worked with the first firm, it is indifferent between offering offers a fixed fee contract $\{f_2\}$ or a milestone only contract based on a probability of success $p(e^{**})$ as long as all rents are extracted from the second firm. However, to support in equilibrium, we require that the TTO offers a milestone only contract with milestone equal to m_2 given by:

$$p(e^{**})[q\pi(x) - m_2 - C] - X = 0 \iff m_2 = q\pi(x) - C - \frac{X}{p(e^{**})}. \quad (20)$$

Thus, the TTO's incentive constraint is

$$\begin{aligned} z(1 - \alpha)p(e^{**})m_2 - K - (1 - zp(e^{**})q)L &\geq -L \\ \iff z(1 - \alpha)[p(e^{**})(q\pi(x) - C) - X] + zp(e^{**})qL &\geq K. \end{aligned} \quad (21)$$

which is satisfied, again, for K sufficiently low.

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:

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

Suppose the inventor works, but deviates and "turns in" the firm for shirking. 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:

$$\alpha zp(e^{**})m_2 - V(e^{**}).$$

Substituting for m_2 in the above, it is easy to see that deviating yields a lower payoff than conforming since $p(e^{**})m^{**} > zp(e^{**})m_2$.

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. However, since the TTO offers a milestone only contract to the second firm, the inventor obtains a payoff of zero in this case, which is less than what it obtains from conforming to the equilibrium strategy:

$$\alpha p(e^{**})m^{**} - V(e^{**}) > 0.$$

Finally, it must be the case that $\{m^{**}, f^{**}\}$ is the contract that maximizes the TTO's expected payoff in the first stage. The relevant part of the TTO's expected payoff is what it obtains with the first firm if the firm is a non-shelver:

$$(1-s)[(1-\alpha)p(e)m + f - (1-p(e)q)L] \quad (22)$$

and the only constraint is given by a non-shelver's participation constraint

$$p(e)[q\pi - m - C] - X - f \geq 0.$$

with inventor effort solving $\max_e \{\alpha p(e)m - V(e)\}$. It is clear that the solution to the maximization of (22) is indeed $\{m^{**}, f^{**}\}$.

8 Appendix B: Proof of Proposition 3

We first derive conditions that must be satisfied in any equilibrium in which shelvers reject the TTO's contract, but non-shelvers accept it and work on development. Existence of such an equilibrium depends on the parameters.

First if such an equilibrium exists, the TTO does not search for a second firm if it observes a technical failure with the first firm. Let $\{m, f\}$ be the contract offered to the first firm. If shelvers reject the TTO's contract, then for K sufficiently low, following a similar argument as in the proof of Proposition 2, the TTO will search for a second firm and offer $\{m^{**}, f^{**}\}$ to that firm. Thus a shelver's payoff from rejecting the contract is

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

Moreover, since the TTO does not search for a second firm upon a technical failure, a shelver would shirk were it to enter. Thus a shelver's payoff from accepting the TTO is clearly

$$\pi^m - f.$$

Therefore a shelver will stay out if and only if

$$f \geq zp(e^{**})qD. \quad (23)$$

Given optimal behavior by the inventor, a non-shelver will accept the TTO's contract if and only if

$$p(e')[q\pi - m - C] - X - f \geq 0. \quad (24)$$

where e' is the solution to

$$\max_e \alpha p(e)m - V(e).$$

The TTO's problem in the first stage is thus to maximize its expected payoff given by

$$(1-\alpha)[(1-s)(p(e')m+f)+s(zp(e^{**})m^{**}-K)]-(1-s)(1-p(e')q)L-s(1-zp(e^{**})q)L \quad (25)$$

subject to (23) and (24). A solution with $m > 0$ (so that $e' > 0$) will exist only if f does not have to be too large to satisfy (23). However, in the limit as D goes to zero, the problem is similar to the case without shelvees, so that we know that a contract satisfying both (23) and (24) exists. By continuity, this will continue to hold true for a range of values of D . Furthermore, it clear that the TTO will want to set the minimum fixed fee consistent with non-shelver not accpeting the contract. This implies that in equilibrium $f = zqp(e')D$. When it exists, let the solution to the above problem be $\{m', f'\}$, where $f' = zqp(e')D > 0 = f^{**}$, from which it follows that $m' < m^{**}$.

To show that for K low, D sufficiently small and z sufficiently large, the contract characterized above is the unique equilibrium in pure strategies, note first that in equilibrium, it cannot be the case that both types of firms enter and work on technical development. In this case, if a technical failure occurs, the equilibrium belief that that the invention does not work must be zero. Thus no second firm will want to license the invention. Therefore shelvees would do better by shirking instead of working. Thus if an equilibrium with both types of firms entering exists, it must be the case that shelvees shirk at the development stage. It follows that if the TTO's contract is $\{m'', f''\}$, its expected payoff is of the form:

$$(1-\alpha)[(1-s)(p(\tilde{e})m''+f'')+sR]-p_FL \quad (26)$$

where \tilde{e} is optimal inventor effort and R denotes expected revenue from licensing to the second firm (which can be zero) and p_F denotes the probability of commercial failure. Clearly $R \leq (zp(e^{**})m^{**}-K)$. Moreover, since in the limit as D goes to 0 and z goes to 1, (25) converges to the TTO's payoff without shelvees, which can easily be shown to be strictly greater than $(1-s)(p(\tilde{e})m''+f'')-p_FL$. This follows from the fact that effort is lower under a contract that accomodates both types of firms including shelvees that shirk at the development stage. For this reason, the probability of commercial failure p_F will also be higher under such a contract. Therefore, there exist values of D and z , \tilde{D}_2 and \tilde{z} such that if $D \leq \tilde{D}_2$ and $z \geq \tilde{z}$, in the unique equilibrium in pure strategies, the TTO offers $\{m', f'\}$.

9 Appendix C: Proof of Proposition 4

We begin the proof of Proposition 4 with (ii) since it is straightforward. From the definition of \tilde{z}_1 , if $z < \tilde{z}_1$, 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.

For (i), note that to ensure participation, expected profits prior to firms finding out their type must be nonnegative (given that effort is e^s). However, recall that

only firms of type G continue and pay m_2 after development. Thus the firm's participation constraint is:

$$p(e^s)[(1-s)(q_G(\pi-C)-m_2)-m_1]-X-f \geq 0, \quad (27)$$

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

$$m_2 \geq q_B(\pi-C). \quad (28)$$

But if (27) holds, then it is clear that a firm of type G wishes to continue in case of a technical success, that is:

$$m_2 < q_G(\pi-C). \quad (29)$$

The TTO's expected payoff from a separating contract if it searches is:

$$\begin{aligned} p(e^s)[(1-s)(1-\alpha)(m_1+m_2+f) &+ s(1-\alpha)(m_1+f) \\ &+sz(1-\alpha)f_2 - sK] \\ + (1-p(e^s)(1-\alpha)f &- (1-p(e^s)q_G(1-s(1-z)))L. \end{aligned} \quad (30)$$

The first two terms multiplied by $p(e^s)$ represent the expected payoff from the first firm (type G with probability $1-s$ and type B with probability s). The second two terms multiplied by $p(e^s)$ represent the expected payoff from taking the license back from a type B firm. The term multiplied by $1-p(e^s)$ is simply payoff 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 (30). Since the TTO will extract all rents from the first firm, it will set the fixed fee f^s such that (27) is binding. Moreover, the TTO's expected payoff, (30), after substituting for f^s , is strictly increasing in both m_1 and m_2 . 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 reposes 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:

$$\text{Maximize } p(e)\alpha[(1-s)q_B(\pi-C)+szq_G(\pi-C)]+f-V(e). \quad (31)$$

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 $e^p(\hat{m})$. Moreover, 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 (31). 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 separating 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 4, we have not shown that milestone payments and annual fees can coexist in the sense that both instruments are strictly positive. m_2 is constrained 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 separating 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 (15), $1 - s < 1$ 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 $(1 - \alpha)(1 - s)p(e^s)$.

10 Appendix D: 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 million 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 federally 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 received 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 universities 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 pharmaceuticals 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		Upfront Fees		Running Royalties		Equity	
	Coef.	t-Stat	Coef.	t-Stat	Coef.	t-Stat	Coef.	t-Stat
EARLY	0.327	1.68 *	-0.732	-3.43 ***	-0.613	-2.81 ***	-0.197	-0.63
CRIT	0.929	3.62 ***	-0.543	-2.20 **	-1.464	-6.19 ***	0.237	0.64
NOTCRIT	-0.162	-0.85	-0.911	-4.45 ***	-1.392	-6.30 ***	-0.385	-1.06
No. Obs.	297		292		300		259	

B. Tests of Equality of Coefficients

Null Hypothesis	Milestone		Upfront Fees		Running Royalties		Equity	
	Chi-Square	Stat	Chi-Square	Stat	Chi-Square	Stat	Chi-Square	Stat
EARLY=CRIT	5.97	**	0.76		16.41	***	1.80	
EARLY=NOTCRIT	7.46	***	0.88		16.84	***	0.35	
CRIT=NOTCRIT	20.07	***	2.89	*	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.