Start-ups, Spin-offs, and Internal Projects

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We examine the incentive problem confronting a firm and employee when the employee privately discovers a significant invention and faces a choice between keeping the invention private and leaving the firm to form a new company (start-up), or transferring knowledge and attempting to gain compensation from the firm (spin-off). We focus on inventions that require little start-up capital and for which property rights are either missing or very weak. In such settings, the employee will sometimes form a new company even though joint profits would have been greater had the invention been developed with the original firm. We also identify when the firm has an incentive to pay a substantial sum to the employee via a spin-off, thereby deterring a start-up. Finally, the basic analysis is applied to examine several issues including specific versus general innovations, trade secret law, and legal "shop rights."

1. Introduction

In many industries, especially newly emerging ones, firm composition and market share change rapidly. New market niches are created, and entry is commonplace. Many of these entrants are composed of the disaffected or ambitious former employees of a more established firm. For example, software houses have spawned other software houses, and university research projects have led to small private firms. Some churning can also be seen in more established markets: principals and partners in management consultancies and law firms often leave their firms to compete directly against their ex-employers. In fact, a recent survey of the founders of 100 of the 1989 Inc. "500" fastest growing private companies found that 71 percent had "replicated or modified an idea encountered through previous employment" (Bhide, 1994: 151).

In this article we examine the incentives faced by an employer and an employee when the employee privately discovers a significant invention. We

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focus on inventions whose market exploitation requires little start-up capital and for which no property rights exist. The lack of property rights creates a fundamental incentive conflict: market exploitation requires only the underlying knowledge regarding the invention, and neither party has a legal recourse for preventing the other from pursuing market rewards. The employee faces a choice between keeping the invention confidential and leaving the firm to start up a new company, or transferring knowledge of the invention and attempting to gain compensation from the firm. With the second option the parties design a contract to provide incentives, and we refer to any organizational relationship predicated on a contract as a spin-off.

Start-up and spin-off organizational incentives determine whether the parties can successfully capture the rents created by the invention. We identify conditions under which the employee can obtain sufficient rents from the firm to avoid a start-up, despite the contracting limitations on spinoffs that are implied by the absence of property rights. We also identify when the employee will start up a new company, even though joint profits would have been larger had the invention been exploited via a spin-off with the original firm. This inefficiency, which obtains despite the ability of the parties to bargain freely over contract terms, results from the basic incentive conflict stemming from the lack of property rights.

Many important innovations are not protected by patents or copyrights and have, at best, limited protection via trade secret laws.[1] In principle, trade secret law will protect employers from having their employees "steal" confidential information. In practice, detection is problematic and court challenges against former employees are difficult to win.[2] Numerous anecdotal examples of new start-ups that compete directly with the employee's previous firm suggest that employees can and probably do develop ideas and leave the firm with them. Given enforcement and litigation problems, trade secret law may not deter an employee from being silent about a discovery made while under the firm's employ, leaving the firm, and then using that discovery as the basis for a new product. In other words, the employee may adopt the view "I'll keep this job until I do something important."

The question of whether inventor-employees will remain with a firm has been addressed in the economics literature by Pakes and Nitzan (1983). They examined a setting where parties have complete information regarding the invention and contracting leads to efficient outcomes. Our analysis provides an information- and incentive-based explanation for inefficient outcomes involving start-ups.[3]

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1. Many forms of intellectual property (e.g., product concepts, customer lists) are neither copyrightable nor patentable. Other potentially valuable discoveries are not patentable because of similarity to "prior art" or because they are "obvious."

2. Trade secret law is seen as having substantial limitations to its effectiveness. In *Kewanee Oil Company v. Bicron Corporation*, 416 U.S. 470 (1974), 94 S. Ct. 1879, 40 L. Ed. 2d 315, for example, Chief Justice Burger noted, "Where patent law acts as a barrier, trade secret law functions relatively as a sieve."

3. In Pakes and Nitzan (1983), the employee can leave the firm to pursue an outside option, an

To analyze start-ups and spin-offs we focus on a polar case: there are no property rights protecting the innovation and the innovation can be costlessly copied by any knowledgable party to whom the innovation has been revealed.[4] In Anton and Yao (1994a) we examined the problem of an independent inventor who has no property rights and, lacking direct access to the market, attempts to sell the invention in a symmetric duopoly market. The present article employs the same no-property-rights framework to address the questions of why we observe former employees organizing start-ups and why firms have difficulty retaining the associated innovations. It also explores briefly several institutional considerations (e.g., trade secret litigation and provisions regarding shop rights) that are triggered by the initial position of the employee as a member of the firm.

The substantive focus on employees and start-ups involves two key differences in assumed market structure relative to our previous work. First, direct access to the market via a start-up contrasts with indirect access via selling the invention to a rival firm. The start-up option is a pivotal difference: a spin-off outcome with the original employer necessarily results when the outside option is a rival firm. This is because a rival firm also has an incentive to expropriate the invention, and the implied reduction in outside rents for the employee is sufficient to support a spin-off structure.

Second, the issue of efficient organization with respect to total surplus hinges on the natural assumption that spin-offs are likely to have a greater profit potential than start-ups. In a symmetric setting, as in our previous article, a start-up has potential market reward equal to that of a spin-off and the issue of organizational efficiency does not arise. Further, because a start-up avoids the risk of expropriation by the employer, it is necessarily more attractive to the employee and, in effect, basic questions regarding start-up and spin-off incentives are assumed away in a symmetric setting.

When will an employee with a valuable invention sell to the firm rather than form a new start-up? Given weak property rights, intuition might suggest a start-up because a firm would pay little for an undemonstrated idea or a demonstrated idea that can be copied and used without legal complications. This intuition, however, is incomplete and not entirely correct. First, with large wealth an employee may be able to secure large rents through a contingent contract that is negotiated prior to revealing knowledge of the discovery to the employer (an ex

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action that reduces the value of an invention to the firm. Because the internal and external value of the invention is observed by all, contracting supports the first-best outcome in which the employee stays depending on whether the internal or external joint surplus is larger. Our analysis emphasizes adverse selection with respect to the employee and the strategic option to reveal the invention to the firm. These features are crucial for the inefficient outcome involving start-ups. See also Aghion and Tirole (1994), Aron (1991), and Demski and Sappington (1991) for analyses related to spin-off incentives.

4. The market value of such innovations is greatest when they involve processes that can be kept secret (e.g., only the results of the process are observable in the market). Such secrets are difficult for competitors to learn. In *Northern Petrochemicals Co. v. Tomlinson*, 484 F.2d 1057 (7th Cir. 1973), the victim of a trade secret theft learned of the theft only after acquiring the firm that had received the secrets.

ante contract). Second, and more importantly, absent large wealth an employee can sometimes obtain sufficient rents to avoid a start-up by first revealing the discovery to the firm and then negotiating a contract (an ex post contract). This is because once the firm learns that the employee has a valuable outside option, the firm is willing to pay the employee to ensure its own monopoly use of the invention. In other circumstances, a start-up will obtain.

The employee is confronted with three strategic options in our model, given that the invention has been privately discovered. First, the employee can remain silent, leave the firm, and form a new company (start-up). The second option is to reveal the invention and risk expropriation, with the possibility that the firm will offer/accept an ex post contract (unconditioned revelation). The final option is to seek an ex ante contract from the firm and delay revealing the discovery until after contractual incentives are established (ex ante contracting). Thus, spin-offs may be governed by ex post or ex ante contracts. In our base case the "efficient" outcome for the invention is monopoly use by the firm, which is assumed to be the joint profit-maximizing outcome. As a benchmark result, we show that ex ante contracts can support the "efficient" outcome, a spin-off in which a contract induces revelation and monopoly use of the invention, but only when the employee has large initial wealth. That contract has a straightforward and familiar incentive structure: the employee posts a large initial bond that is forfeited unless the spin-off earns monopoly profits. Adverse selection, however, will cause this result to collapse when wealth is small, because such an ex ante contract will be attractive to an employee without the invention.

Unconditioned revelation solves the adverse selection problem—freely revealing the invention eliminates the information asymmetry—and still leaves the firm with an incentive to pay the employee to preserve the firm's monopoly use of the invention (against the duopoly use should the employee begin a start-up).[5] Furthermore, limited wealth ceases to be a contracting obstacle. However, because the lack of property rights allows the firm the option of "expropriating" the (revealed) invention—using it without payment to the employee—the amount the firm is willing to pay is limited to the difference between monopoly and duopoly profit levels. For unconditioned revelation to occur, an ex post contract must pay the employee enough to avoid a start-up and yet leave the firm with sufficient profits to discourage expropriation.

We show when this condition cannot be satisfied, analyze the determining factors, and identify the settings in which inefficient start-up outcomes are more likely to occur. When the condition holds, ex post contracting following unconditional revelation can overcome the start-up incentive and a spin-off can be supported.[6] This condition will tend to hold for "general" innovations and thus lead to spin-offs, while "specific" innovations lead to start-ups.

5. The employee's idea is unlikely to be protected through confidentiality agreements because firms typically require unsolicited inventors to sign a waiver stating that no confidential relationship exists (Cheung, 1982).

6. Our analysis of unconditioned revelation is related to the problem of strategic information revelation. Different aspects of this problem are studied in Okuno-Fujiwara, Postlewaite, and

Relative to the "efficient" (first-best) outcome of monopoly use by the firm, the firm and employee in our analysis face three obstacles: adverse selection due to private discovery, limited liability of the employee, and the restrictions on contracts implied by no property rights. When limited liability does not bind (large employee wealth), the first-best remains feasible and ex ante contracts support a monopoly spin-off outcome. When limited liability binds, ex post contracts can support a spin-off, and the first-best remains feasible only if the incentive of the firm to expropriate a revealed invention is not too strong. Otherwise, the first-best is rendered infeasible and cannot be supported by mutually beneficial contracting between the parties. In this event, the start-up outcome results from the three contracting obstacles; as the parties cannot design a contract that improves on this outcome, start-ups are efficient in the (second-best) sense that the parties can do no better given the three contracting obstacles implied by the environment.

We begin with a description of the model and then analyze the basic model in Sections 3 and 4. In Section 5 we discuss the settings where start-ups are more likely and assess the impact of complementary assets, external finance options, and reputation effects. We conclude with a brief analysis of relevant issues that involve less extreme information and property right structures.

2. The Model

We are interested in the forces that determine whether rents from a valuable invention are captured through a start-up, a spin-off, or an internal venture. Suppose that a firm has been pursuing an R&D project in-house.[7] The employee may privately learn of a discovery (invention) that would make the project successful without the firm or others in the firm also learning of the discovery.

The outcomes of a start-up, a spin-off , and an internal venture refer to the following three possibilities. Due to weak property rights, the employee can leave the firm and use the discovery in a *start-up* venture that is completely independent of the firm. Alternatively, the employee may reveal the discovery to the firm, in which case the firm learns if the invention is "good" and acquires the relevant know-how needed to independently bring the invention to market. If the firm acts independently, without contracting with the employee, we say the firm has pursued an *internal project*. Finally, if the firm and employee enter into a contract, either before or after the invention is revealed, we say that the firm has created a *spin-off*. We use the term spin-off to include all organizational arrangements predicated on contracts between the firm and the employee.[8]

Suzumura (1990), where revelation involves certifiable public disclosures. See also Bhattacharya, Glazer, and Sappington (1992) who analyze revelation in research joint ventures, where parties may be concerned that revealed information will benefit competitors in their own R&D efforts.

7. We suppose that the project gives the firm a monopoly position. It is straightforward to extend the analysis to an oligopoly setting.

8. Many companies cultivate new innovations by forming separate units and then tying a "product champion's" compensation at least partially to the performance of those units (see, e.g., "Thermo Electron Uses an Unusual Strategy to Create Products," *Wall Street Journal*, August 5, 1993, 1).

These possibilities are implemented through an adaptation of the model used in Anton and Yao (1994a), as follows. The employee privately obtains a good invention with probability q and then faces three options.[9] First, the employee can leave the firm without revealing the discovery, and form a start-up. Second, the employee can reveal (freely) the discovery to the firm—we refer to this as the unconditioned revelation option. The firm and employee may then negotiate an ex post spin-off contract. With or without a contract, the employee still may form a start-up (recall the lack of property rights). The third possibility is ex ante contracting—contracting prior to revealing the invention. If the parties agree to such a contract, the employee then decides whether to reveal the invention and whether to form a start-up. If the parties fail to agree, the employee may then pursue either of the other two options.

In all cases we assume that the firm has a probability α of its R&D unit independently discovering the invention. Thus, the employee cannot exercise perfect control over the flow of information from the R&D project to the firm. For simplicity, this discovery is modeled as occurring subsequent to all other actions and just prior to the "market outcome" in which payoffs are determined.

Now consider the structure of gross profit flows. There are four outcomes (states of the world) and corresponding gross profit levels, with each outcome depending on who is using the invention. We specify profits in reduced form. In the status quo state where no invention is available to either party, the firm earns π_0 and the employee earns $\sigma_0 \equiv 0$. A *monopoly* for the start-up occurs where only the start-up has the invention, and profits are σ_M for the start-up and π_L for the ("loser") firm. A monopoly for the firm results in profits of π_M for the firm and there is no start-up. *Duopoly* is the case where both have the invention; profits are σ_D and π_D. We make the basic profit assumption that $\pi_M > \sigma_M + \pi_L > \pi_D + \sigma_D$: monopoly use by the firm maximizes joint profit and a start-up is always (profit) inefficient. Either form of monopoly is superior to industry duopoly in terms of joint profits. We also assume profit levels that ensure it is profitable to make use of the invention, specifically, $\pi_M > \pi_0$, $\pi_D > \pi_L$, and $\sigma_D > 0$. Together with the basic profit assumption, these conditions imply that $\pi_M > \pi_D$ and $\sigma_M > \sigma_D$.[10]

All parties are assumed to be risk neutral and to maximize expected profits. Expected gross profits of the employee and firm, which vary with the independent realization of the firm's R&D efforts (probability α of success), are as follows. First, an employee who possesses a good invention and forms a start-up without revealing the invention to the firm, has expected profits of $(1-\alpha)\sigma_M + \alpha\sigma_D$, while expected profits for the firm are $(1-\alpha)\pi_L + \alpha\pi_D$. Second, when an employee has a good invention, reveals, and does not form a start-up, expected profits are 0 for the employee and π_M for the firm. Next, when an employee has a good invention, reveals, and forms a start-up, expected

9. When a good invention is not observed, the default of no revelation occurs.

10. Altering the order of gross profits—e.g., by having $\pi_0 > \pi_M$—corresponds to an incentive for "shelving" the invention. There the firm may benefit by offering a "spin-off" contract that suppresses the use of the invention.

profits are σ_D for the employee and π_D for the firm. Finally, if the employee does not have a good invention (or does nothing with it), then expected profits are 0 for the employee and $(1-\alpha)\pi_0 + \alpha\pi_M$ for the firm.

The opportunity for an ex post contract occurs if the employee has revealed to the firm. An ex post contract specifies two payments, $R = (R_M, R_D)$, where R_M is the payment by the firm to the employee when the monopoly outcome for the firm occurs and R_D is the payment when duopoly occurs. Monopoly and duopoly are the only possible outcomes once the employee has revealed to the firm. The duopoly outcome occurs if the employee subsequently forms a start-up.

An ex ante contract specifies payments $R = (R_0, R_M, R_\sigma, R_D)$, where the subscripts correspond, respectively, to the status quo of no invention, monopoly by the firm, monopoly by the start-up, and duopoly outcomes. Any contract payment from the employee to the firm is limited by the employee's wealth, L. Hence, payments satisfy $R_x \geq -L$ for each outcome x.

A contract R is efficient if it satisfies two basic properties: R is mutually acceptable (each party weakly prefers to accept R, with strict preference for at least one party) and undominated (there exists no Pareto-improving alternative contract). We assume that the firm and employee will sign an efficient contract, provided that one exists. No specific bargaining structure need be imposed; our results refer to the set of efficient contracts and do not depend on how the surplus is divided. With regard to contractual completeness, we assume that gross profits are verifiable so that payments (R_x) can be enforced for the relevant outcomes. Contracts are incomplete, however, in that the lack of legal property rights prevents the parties from assigning property rights via contracts. In short, it is the consequence of *using* the invention but not the underlying *source* of the invention that forms the basis for contracting, and this consequence is only imperfectly correlated with the underlying source of invention.

3. The Ex Post Incentive for a Start-up Versus a Spin-off

We now turn to the analysis of the factors that determine whether a start-up, spin-off, or internal project is the outcome. The analysis leads to two basic results. First, the employee can use "unconditional revelation" to obtain an ex post contract that pays at least what the employee could make competing against the firm (i.e., duopoly profit) and, depending on assumptions about bargaining, considerably more. Second, it is sometimes impossible for the employee's payoff from an ex post contract to exceed the payoff from not revealing and choosing a start-up. In such cases an inefficient start-up will be chosen over a more efficient spin-off organizational form. We begin with the case of unconditioned revelation and ex post contracting. The analysis of ex ante contracting appears in Section 4.

3.1 Basic Analysis

Suppose the employee has a good invention. By forming a start-up and not revealing to the firm, the employee receives a payoff of $(1-\alpha)\sigma_M + \alpha\sigma_D$. Suppose, instead, that the employee reveals. By rejecting a contract, the employee

can still form a start-up, but the payoff is now σ_D. The firm, by rejecting, can guarantee itself π_D. The only decision remaining after an ex post contract is signed is the employee's decision to form a start-up. It is easy to show that an efficient contract prevents a start-up.

Now consider an (R_M, R_D) resulting in no start-up and a monopoly for the firm. This means $R_M \geq R_D + \sigma_D$, as the employee must choose not to form a start-up given the contract. For the inventor to accept, $R_M \geq \sigma_D$. For the firm to accept, $\pi_M - R_M \geq \pi_D$, as the firm will never pay more than the added value of monopoly over duopoly. Then, the monopoly payment, R_M, satisfies $\pi_M - \pi_D \geq R_M \geq \sigma_D$. While the duopoly payment is not payoff relevant, it must support the incentive not to form a start-up. Under the standard assumption that monopoly profits exceed total duopoly profits, such an R_M payment always exists. The range for R_M reflects the possible division of monopoly surplus (relative to duopoly) between the firm and the employee, given revelation.

Next, and this is the crucial step, consider the initial decision to reveal versus to form a start-up. The employee will reveal only if $R_M \geq (1-\alpha)\sigma_M + \alpha\sigma_D$. Because the set of efficient contracts has the monopoly payment of R_M bounded above by $\pi_M - \pi_D$, we see that no such R_M will exist when $\pi_M - \pi_D < (1-\alpha)\sigma_M + \alpha\sigma_D$. Thus, we have demonstrated the following proposition.

Proposition 1. The set of efficient ex post contracts is nonempty and consists of all pairs (R_M, R_D) such that $\sigma_D \leq R_M \leq \pi_M - \pi_D$ and $R_D \leq 0$. The payoff to the employee from a start-up is greater than the payoff from every efficient ex post contract if and only if

$$\pi_M - \pi_D < (1-\alpha)\sigma_M + \alpha\sigma_D. \tag{1}$$

Inequality (1) implies that when the value of monopoly to the firm fails to exceed the value of a start-up monopoly to the employee by at least duopoly profits of the firm, there is a basic incentive conflict leading to a start-up. Simply put, it is not possible to capture the added value over a start-up when the absence of property rights allows for a start-up. Significantly, an employee will choose to form a start-up even where the joint profit potential of a spin-off is greater.[11]

3.2 Bargaining Power

Now consider ex post contracting in relation to bargaining power. Suppose that the firm has bargaining power allowing it to make a take-it-or-leave-it offer to the employee. Clearly, the ex post offer must have $R_M = \sigma_D$ so that the employee is pushed to indifference. As a result, the employee will choose not to reveal and will pursue a start-up directly since we always have $(1-\alpha)\sigma_M + \alpha\sigma_D > \sigma_D$.

Corollary 1. Suppose that contracting involves a take-it-or-leave-it offer from the firm to the employee. Then, independent of Condition (1), the employee pursues a start-up.

11. A familiar example provides a useful reference point. Suppose that $\pi_D = (4/9)\pi_M$, as with linear demand and symmetric Cournot duopoly. Pushing α to 0, then Condition (1) will hold as long as σ_M is at least $(5/9)\pi_M$.

The reason the employee pursues a start-up is that unconditioned revelation eliminates the chance for a start-up monopoly and, ex post, the firm will offer only a payment based on the smaller duopoly value of a start-up. Thus, we see that Proposition 1 is conservative with respect to the potential for the inefficient start-up outcome. On the other hand, if the employee has some bargaining power vis-à-vis the firm, then Condition (1) comes back into play.

3.3 Specific Versus General Innovations

In practice, innovations often can be distinguished by the extent to which their value is tied to a particular firm's product (a "specific" innovation) or is valuable on its own or with a wide variety of products in a given industry (a "general" innovation). Software products that have been written specifically to improve the performance of a given product (e.g., WordPerfect word processor) are examples of specific innovations. Examples of general innovations include airline yield management systems and computer file management utilities. Proposition 1 has several implications for start-up and spin-off incentives in relation to the type of innovation.

Consider a specific innovation. While exclusive use of the innovation would allow either the firm or the start-up to earn a profit increment ($\pi_M > \pi_0, \sigma_M > 0$), the firm often will have a critical advantage in a duopoly competition. For example, when the innovation is completely product specific, the firm may bundle the specific innovation with the basic product, leaving the start-up with no market share (except perhaps for share from previous buyers of the old unbundled product). In the extreme no-market-share case, we have $\pi_M = \pi_D$ and $\sigma_D = 0$, so (1) directly implies a start-up.[12]

In contrast, our analysis suggests that spin-off outcomes will be formed in response to general innovations. This is because the firm and a start-up would now compete with each other to sell the innovation to other firms in the industry. At an extreme, this could lead to $\pi_D = \sigma_D = 0$—as, for example, when duopoly price competition leads to a complete dissipation of the rents generated by the innovation. Either form of monopoly (with respect to the innovation), however, allows the firm or the start-up to capture these rents and (1) directly implies that a spin-off can be supported.

3.4 Outside Options

The outside option of the employee is important for start-up versus spin-off incentives. To identify this effect, we compare the present analysis with that

12. It is straightforward to construct models of oligopoly competition with these payoffs, as well as the payoffs for a general innovation. The extreme cases are based on a price competition duopoly model involving horizontal differentiation among buyers for two basic products offered by different firms and vertical differentiation for the innovation, which takes the form of an "add-on" feature to the basic products. The analysis can also be applied to address how start-up and spin-off incentives are affected by changes in gross profit flows (such as π_M, $\pi_M - \pi_D$, etc.), perhaps due to the presence of complementary inputs held by the firm. We are grateful to Raffi Amit for a helpful discussion on these points.

in Anton and Yao (1994a). There, we examined the problem of an independent inventor who lacks property rights and has no direct access to the market. Instead, the inventor tries to sell the invention to one (or more) firm(s) in a symmetric duopoly market. While revealing the invention risks expropriation, limited capital of the inventor renders an ex ante contracting approach ineffective. In equilibrium, an inventor with nearly no wealth reveals unconditionally to one firm and receives a payment on the order of a firm's duopoly profit level. Because the inventor has a credible threat to reveal the invention to a rival firm, the approached firm offers an ex post contract that eliminates the incentive to exercise that threat, thereby preserving a monopoly position with the innovation.

The option to form a start-up contrasts with the option of selling to a rival firm. While the profit potential of the invention with an established rival firm may dominate that of a start-up, adverse selection and expropriation problems also arise. To assess the impact on start-up and spin-off incentives, consider how the analysis is affected when the employee has no direct start-up option; instead, suppose that the option is to bargain with a "rival" that is symmetric to the other firm except not engaged in relevant R&D. If the employee bypasses the original employer (henceforth, the "firm") and reveals to the rival (or the employee and firm fail to agree on a contract after revelation has occurred), then gross profits for the rival are at best $(1-\alpha)\pi_M + \alpha\pi_D$ and at worst π_D, depending on whether the invention is revealed to the original employer. Under the generous assumption that the employee gets all of the surplus, the most the employee can ever expect from bypassing the firm and revealing to its rival is $(1-\alpha)(\pi_M - \pi_D)$, as the rival will never pay more to preserve a monopoly in the invention. As a result, a spin-off with the firm can always be supported, since $\pi_M - \pi_D > (1-\alpha)(\pi_M - \sigma_D)$, the analogue of (1), necessarily holds. Thus, the direct start-up option plays a crucial role in our analysis. When the outside option is instead a rival firm, where an additional expropriation constraint comes into play, spin-off incentives become dominant and the choice of an employee to leave the firm is rendered moot.

4. Ex Ante Incentives

In addition to ex post contracting, we must consider the potential for ex ante contracting. The potential value of ex ante contracting depends critically on Condition (1). The substantive case for ex ante contracts arises when (1) holds and, as Proposition 1 asserts, ex post contracting is unable to prevent a start-up. When Condition (1) fails, Proposition 1 shows that ex post contracting supports a spin-off. In this event, it can be shown that ex ante contracting is of no additional value to the parties, the reason being that an efficient ex ante contract will simply duplicate the outcome and payments of an efficient ex post contract. Thus, we fix (1) as a maintained assumption and focus on ex ante contracting when ex post contracting cannot prevent a start-up.

Prior to revelation, the firm cannot know whether it faces an informed employee or an uninformed one. Adverse selection is thus an issue, and an ex ante contract may screen out uninformed employees or pool them with informed

employees. An efficient ex ante contract necessarily provides incentives to reveal the discovery while preventing a start-up. Formally, we have Lemma 1.

Lemma 1. Suppose R is an efficient ex ante contract. Then R satisfies

$$R_M \geq \text{Max}\{R_D+\sigma_D, (1-\alpha)R_0+\alpha R_M, (1-\alpha)(R_L+\sigma_M)+\alpha(R_D+\sigma_D)\}. \quad (2)$$

When payments satisfy Condition (2), informed employee actions under R will lead to a monopoly for the firm. Lemma 1, which applies whether R is a screening contract or a pooling contract, provides us with the basic structure of an efficient ex ante contract: a spin-off is generated by specifying a monopoly payment of R_M that is sufficient to induce revelation and prevent a start-up. But when do these contracts exist? We begin with the case of screening and then turn to pooling.

The conditions for existence of an efficient screening contract consist of the screening condition of $(1-\alpha)R_0+\alpha R_M < 0$, the incentive condition of (2), the limited liability requirement of $R_x \geq -L$, and mutual acceptability. Mutual acceptability reduces to

$$\pi_M - [(1-\alpha)\pi_L + \alpha\pi_D] \geq R_M \geq (1-\alpha)\sigma_M + \alpha\sigma_D, \quad (3)$$

which is the analog to Condition (1) for ex post contracts. In contrast to (1), the basic payoff assumption of $\pi_M > \sigma_M + \pi_L > \sigma_D + \pi_D$ implies that the interval for monopoly payments R_M in (3) must exist. The reason is that ex ante contracting is associated with a lower acceptance threshold for the firm since, prior to revelation, the firm is not assured of having the invention and therefore of obtaining at least π_D. Because the prospect of π_L is greater, ex ante contracting relaxes the condition for acceptability.

To screen an uninformed employee, the likelihood of receiving a monopoly payment of R_M must be offset by a sufficiently negative payment of R_0, namely $R_0 < -\alpha(1-\alpha)^{-1}R_M$. Thus, there is a basic conflict between mutual acceptability, screening, and the employee's limited wealth. Formally, we have Proposition 2.

Proposition 2. There exists an efficient ex ante screening contract if and only if $L > \alpha(1-\alpha)^{-1}[(1-\alpha)\sigma_M + \alpha\sigma_D]$. The set of contracts then consists of $(R_0, R_M, R_\sigma, R_D)$ such that R_M satisfies (3) and $R_M < \alpha^{-1}(1-\alpha)L$ and, without loss of generality, $R_0 = R_\sigma = R_D = -L$.

When L is above the threshold, efficient ex ante screening contracts exist and they support a spin-off. When L is below the threshold, efficient ex ante screening contracts fail to exist. Intuitively, limited wealth makes it impossible to overcome the start-up incentive of an informed employee. To gain some intuition regarding the size of the threshold, consider the inequality for L and imagine an R&D project that yields a payoff of σ_M with probability α, and 0 otherwise. Condition (1) implies that σ_M is a significant fraction of π_M. Since the firm would be willing to spend an amount approaching $\alpha\pi_M$ on a project that yields π_M with probability α, the threshold for L is on the order of a sizable percentage of such an R&D budget.

Turning now to the possibility of pooling contracts, the existence conditions consist of the pooling condition of $(1-\alpha)R_0+\alpha R_M \geq 0$, the incentive condition of (2), the limited liability condition of $R_x \geq -L$, and mutual acceptability.[13] The analysis of pooling involves more technical issues than that of screening (see the Appendix). The main result of interest is Proposition 3.

Proposition 3. Suppose that $(1-\alpha)\sigma_M + \alpha\sigma_D > \hat{R}$, where $\hat{R}$ is a threshold profit level that depends on α, q, and gross profits of the firm. Then there exists an efficient ex ante pooling contract if and only if

$$L > \frac{q+\alpha(1-q)}{(1-q)(1-\alpha)}\left[(1-\alpha)\sigma_M + \alpha\sigma_D - \hat{R}\right].$$

As with screening, small wealth is problematic for the existence of pooling contracts. When a start-up is a relatively valuable option (above $\hat{R}$), then the monopoly payment must also be large; small L, however, restricts the size of R_0. As a result, the firm will eventually reject any pooling contract (as L declines).

We summarize our results for pooling and separating ex ante contracts as follows.

Corollary 2. Suppose Condition (1) holds and that $\hat{R} > (1-\alpha)\sigma_M + \alpha\sigma_D$. Then as $L \to 0$, so that the wealth of the employee necessarily becomes small relative to the value of the discovery, the employee will pursue a start-up and will not reveal to the firm. For L above the minimum threshold level, the firm and employee pursue a spin-off governed by an ex ante contract.

5. Discussion

Our model predicts that the frequency of start-ups will increase as (i) employees have limited access to funds relative to the value of the invention; (ii) the expected profits of a monopoly with a start-up are closer in size to the expected profits of a monopoly under a spin-off, or the profit increment of a monopoly under a spinoff over duopoly competition with a start-up is small; and (iii) the firm has considerable negotiating leverage over the employee.

The limited-funds condition is an issue in two ways. First, the success of a start-up depends on the availability of sufficient capital to support the start-up. Second, sufficient funds also create the possibility of employing high-paying ex ante contracts that rely on an employee's ability to put up a large performance bond, roughly of a magnitude similar to that of the expected value of the invention. While both ex ante and ex post contracting rely on the viability of contracts

13. The acceptance condition for an informed employee remains $R_M \geq (1-\alpha)\sigma_M + \alpha\sigma_D$. For the firm the acceptance condition works out to be

$$\hat{R} \equiv \frac{q}{q+\alpha(1-q)}\{\pi_M - [(1-\alpha)\pi_L + \alpha\pi_D]\} \geq R_M + \frac{(1-q)(1-\alpha)}{q+\alpha(1-q)}R_0,$$

as the firm must account for pooling with uninformed employees.

based on observable outcomes, the effective use of ex ante contracts also depends on a more stringent set of assumptions (e.g., about common information) which, when relaxed, will increase the difficulties of ex ante agreement.

One implication of these limited-funds considerations is that we should observe start-ups serving niche markets—small markets that are not well served by existing product or service offerings—because start-ups in such markets typically require less capital than start-ups based around more "revolutionary" ideas (Bhide, 1994). Note that even if capital requirements of such markets covary positively with payoffs to a start-up, the ability of an employee/entrepreneur to negotiate ex ante contracts is not necessarily enhanced (see Propositions 2 and 3).

The limited-funds condition might also be overcome through the use of capital sources outside the firm, such as a venture capitalist (VC). In this context, providing capital for a performance bond in an ex ante contract with the firm involves a verification role for the VC.[14] The basic issue is how much of the entrepreneur's potential profit will be siphoned away to the VC, especially when the VC plays a verifying intermediary role. While a full discussion of using a VC is beyond the scope of this article, we are dubious about the attractiveness of this option to an employee-inventor who lacks property rights. In such a setting, it will be difficult for the employee to play VCs against one another, and there is also a serious possibility that the VC will expropriate the invention.[15] Finally, using a VC involves additional loss in time to market and attempts to expedite such arrangements often will involve increasing the VC's share of the profits.

Turning to Conditions (2) and (3), we ask what conditions tend to make a start-up less efficient than a spin-off. Teece (1986) discusses the importance of complementary assets for appropriating rents from technologies. Such assets may include complementary technologies and know-how, distribution systems, marketing assets, etc. The potential for bundling an "add on" innovation with an existing product, which we discussed above, provides an example of this complementary effect. To the extent that these complementary assets are important to earning profits from the innovation in question, a start-up is much less likely to obtain the same magnitude of profits as a spin-off.

Our model, then, predicts that start-ups are more likely when rent capture does not depend on complementary assets being in place or, alternatively, when a start-up can acquire complementary assets at competitive prices. These situations appear to fit many service industries (e.g., consulting) where the complementary assets are either reasonably easy to reproduce or of minor importance.

14. Chan, Siegel, and Thakor (1990) note some difficulties related to a sale of a project by a VC who has private information—a situation similar to that of a VC acting in a verification role.

15. A VC may be able to develop a reputation for not expropriating inventions. However, in this setting such reputations may be difficult to develop because there are few repeat interactions among the concerned parties over different inventions and detection (and confirmation) of expropriation may be difficult, given the lack of tangible property and the naturally high failure rates expected from risky VC-backed projects.

Easy access to complementary assets makes entry into many industries much easier than one might expect. In the microprocessor industry, for example, "foundaries" for the production of chips (e.g., Texas Instruments) are available for chip designers (e.g., Cyrix). Not only do these foundaries circumvent the problem of production facilities and know-how, they also provide access to patents that might otherwise block new chip design and production. Even easier entry is available to "garage" software writers (e.g., employees of software firms) who can take advantage of publishers to get their software produced and distributed.

The model also suggests that the employee's firm might try to avoid startups by developing a reputation not to underpay in a spin-off contract, say, after the employee unconditionally revealed the invention. (See Corollary 1.) Again, there are substantial barriers. First, firms with a poor (or no) reputation on this issue may have few opportunities to develop such a reputation, because no inventor will freely reveal to the firm. Second, innovations come in different sizes, and the probability of independent discovery by the firm is difficult for others to assess. Consequently, a good reputation would be difficult to develop because "underpaying," as opposed to no payment at all, is difficult for outsiders to identify and confirm.[16] The issue is further clouded in that the firm may be justifiably reluctant to be generous with an employee whom the firm might believe stole the secret in the first place.

6. Extensions: Property Rights and Other Institutions

The stylized model of the employee's decision to start up or spin off can be extended to explore many related issues. Here we mention three issues that are developed in more detail in Anton and Yao (1994b). What happens when the employee has some degree of property right protection? Will more effective trade secret protection prevent or encourage start-ups? How would employer "shop rights" affect the analysis?

6.1 Partial Property Right Protection

Our treatment of revelation combines two related but conceptually distinct effects: when the employee reveals, the firm not only learns that the employee has a valuable invention but also acquires the relevant know-how for imitating the invention. This revelation of value and know-how are decoupled, for example, when it is possible to demonstrate product performance without necessarily divulging the metaphorical "secret ingredient."[17] Such a decoupling gives the

16. A simple and observable contractual commitment used by some firms is to pay a prespecified flat royalty rate on profits from the innovation to the employee-inventor. A prespecified rate, however, will necessarily fail to deter a start-up precisely when the start-up payoffs are relatively high. Rewarding innovations when property rights are weak also has the drawback of distorting innovative effort away from innovations where property rights are expected to be stronger (e.g., patentable). Our model, of course, does not address these effort incentives. See Aghion and Tirole (1994) for an analysis of property right assignments and effort incentives.

17. For example, the speed, accuracy or features of software products may be demonstrated without revealing the underlying algorithms or code.

employee an "informational property right" (that becomes stronger with further decoupling) and increases the attractiveness of spin-offs over start-ups. Intuitively, decoupling eliminates the adverse selection problem while reducing the risk of expropriation by the firm.

6.2 Better Trade Secret Protection

Implicitly, our model treats trade secret law as an exogenous effect incorporated in the final expected payoffs. The choice of the inventor to reveal or to start up his own firm, however, has differential implications for the impact of trade secret litigation on payoffs and outcomes. For example, if an inventor revealed his invention while still an employee of the firm, the timing of the revelation would likely make it easier for the firm to win a trade secret suit against the employee. Thus the impact of trade secret litigation will be to reduce the payoff (of the employee relative to the firm) associated with going outside the firm after the invention has been revealed. Given revelation, the duopoly threat of the firm is strengthened and the difference of $\pi_M - \pi_D$ in Condition (1) is reduced in value, reflecting that the firm is less willing to pay for a monopoly when the prospects for trade secret litigation improve. The net result is that the employee is *more* likely to pursue a start-up and less likely to reveal to the firm.

6.3 Employer Shop Rights

In general, the law makes a rough distinction, based on the relationship between the invention and the duties of the employee, among inventions that are alleged to have been discovered by employees using company resources. If there is a close relationship, inventions belong to the firm; if not, the firm is given free, nonexclusive use ("shop rights") of the inventions, but the firm cannot sell the inventions or prevent the inventor from using or selling the inventions.[18] If the firm does not learn of the employee's innovation, the shop right will remain unexercised and the analysis of the employee's choice will be the same as our basic analysis. If, however, the firm learns of the innovation because, for example, the employee has acquired property rights (e.g., a patent which reveals the innovation but excludes rivals), then the firm can exercise its shop rights, but cannot control the use of the innovation by the employee. The situation is then analogous to the contracting situation after unconditioned revelation: the firm and the inventor both have free access to the innovation, but their joint payoffs are greatest under monopoly use by the firm. If both use the innovation, both expect only to earn duopoly profits. Because the exercised shop right eliminates the option of a start-up monopoly, an efficient ex post contract can support a spin-off.

18. See *McClurg v. Kingsland*, 42 U.S. (1 How.) 202 (1843) and, e.g., *Francklyn v. Guilford Packing Co.*, 695 F.2d 1158 (9th Cir. 1983) and *Wommack v. Durham Pecan Co., Inc.*, 715 F.2d 962 (5th Cir. 1983).

Appendix: Proofs

Proof of Lemma 1. An informed employee under contract R optimally decides whether to reveal to the firm and whether to form a start-up. We show that only the choice of revelation and no start-up is consistent with efficiency. We treat screening and pooling contracts in turn.

Case A. $(1-\alpha)R_0 + \alpha R_M < 0$ and R screens uninformed employees. Suppose first that an informed employee chooses not to reveal and not to start up. The employee accepts if $(1-\alpha)R_0 + \alpha R_M \geq (1-\alpha)\sigma_M + \alpha\sigma_D$, but this contradicts screening. Now suppose the choice is to reveal and to start up. For the employee to accept, $R_D + \sigma_D \geq (1-\alpha)\sigma_M + \alpha\sigma_D$, and for the firm $\pi_D - R_D \geq (1-\alpha)\pi_L + \alpha\pi_D$. Combining, $\pi_D - \pi_L \geq \sigma_M - \sigma_D$, but this contradicts the basic profit assumption. Finally, suppose the choice is not to reveal and to start up. For the employee to accept, $(1-\alpha)(R_L+\sigma_M)+\alpha(R_D+\sigma_D) \geq (1-\alpha)\sigma_M + \alpha\sigma_D$. For the firm to accept, $(1-\alpha)(\pi_L - R_L) + \alpha(\pi_D - R_D) \geq (1-\alpha)\pi_L+\alpha\pi_D$. Simplifying and combining, we see that $(1-\alpha)R_L+\alpha R_D = 0$. Thus, the outcome is the same as when the employee refuses the contract and forms a start-up. This leaves both parties indifferent, which contradicts strict preference.

Case B. $(1-\alpha)R_0 + \alpha R_M \geq 0$ and R pools uninformed employees with informed ones. First, we show that the choice of no revelation and a start-up as well as the choice of revelation and a start-up are not optimal for an informed employee.

If the choice is no revelation and a start-up, then acceptability for the (informed) employee reduces to $(1-\alpha)R_L+\alpha R_D \geq 0$. By pooling, the employee is informed with q and uninformed with $1-q$, and acceptability for the firm reduces to $-(1-q)[(1-\alpha)R_0+\alpha R_M] \geq q[(1-\alpha)R_L+\alpha R_D]$. Combining this last inequality with the pooling condition and (informed) employee acceptability then yields $(1-\alpha)R_0+\alpha R_M = (1-\alpha)R_L+\alpha R_D = 0$. All parties are then indifferent, which contradicts strict preference. Now suppose the choice is revelation and a start-up. For the (informed) employee to accept, $R_D \geq (1-\alpha)(\sigma_M-\sigma_D)$, and for the firm to accept, $q(1-\alpha)(\pi_D-\pi_L) \geq qR_D+(1-q)[(1-\alpha)R_0+\alpha R_M]$. By pooling, $(1-\alpha)(\pi_D-\pi_L) \geq R_D$. Combining with acceptability for the employee yields $\pi_D-\pi_L \geq \sigma_M-\sigma_D$, contradicting the basic profit assumption.

We now show that if R induces no revelation and no start-up, then R is inconsistent with efficiency. We will construct an R' that strictly dominates R, where R' induces revelation and no start-up. Given R, define R' as: $R'_M = u+\epsilon$, $R'_0 = u - \alpha(1-\alpha)^{-1}\epsilon$ and $R'_L = R'_D = -L$, where $(1-\alpha)R_0 + \alpha R_M < u < (1-q)^{-1}\{(1-\alpha)R_0 + \alpha R_M + q(1-\alpha)(\pi_M - \pi_0)\}$, and $0 < \epsilon < \alpha(1-\alpha)^{-1}[u - (1-\alpha)R_0 - \alpha R_M]$ hold for (u, ϵ). Because $\pi_M - \pi_0 > 0$, u clearly exists and, therefore, so does ϵ. It is straightforward to verify that these values for u and ϵ imply that (i) an informed employee under R' will reveal and not start up, and (ii) all parties, the firm and an informed or uninformed employee, strictly prefer R' to R. Then, R' strictly dominates R.

Thus, the choice of reveal and no start-up must be optimal and (2) must hold.

Q.E.D.

Proof of Proposition 2. Suppose $L > \alpha(1-\alpha)^{-1}[(1-\alpha)\sigma_M + \alpha\sigma_D]$. It is straightforward to verify that R, as specified in the proposition, satisfies screening, Condition (2), limited liability, and mutual acceptability. Thus efficient screening contracts exist.

Now suppose $L \leq \alpha(1-\alpha)^{-1}[(1-\alpha)\sigma_M + \alpha\sigma_D]$. Limited liability and screening imply $R_M < (1-\alpha)\alpha^{-1}L$. By the case assumption for L, R_M cannot satisfy Condition (3) and so mutual acceptability fails. Thus, no efficient screening contracts exist in this case.

For the final claim, note that efficient screening contracts satisfy Condition (3), while screening and limited liability imply $R_M < \alpha^{-1}(1-\alpha)L$. Then, as only R_M is payoff relevant for an efficient screening contract, we can set $R_0 = R_L = R_D = -L$ and maintain efficiency and screening. Q.E.D.

Proof of Proposition 3. The existence conditions for pooling imply that R is undominated. Further, we can set $R_D = R_L = -L$ without loss of generality. Existence is then equivalent to (R_M, R_0) that satisfy $\hat{R} \geq R_M + [q + \alpha(1-q)]^{-1}(1-q)(1-\alpha)R_0$, $(1-\alpha)R_0 + \alpha R_M \geq 0$, and $R_M \geq (1-\alpha)\sigma_M + \alpha\sigma_D$. There are two cases. First, suppose $(1-\alpha)\sigma_M + \alpha\sigma_D > \hat{R}$. It is straightforward to verify that the condition on L in Proposition 3 is necessary and sufficient for (R_M, R_0) to exist. When $(1-\alpha)\sigma_M + \alpha\sigma_D \leq \hat{R}$, the conditions for (R_M, R_0) hold for all $L \geq 0$ and pooling contracts exists for all $L \geq 0$ in this case. See Anton and Yao (1994b) for details of the proof. Q.E.D.

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