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Intellectual Property Protection and Firm Innovation

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Abstract

This paper studies the question of whether and how an employee innovator should commercialize an innovation, when doing so within the firm is less costly than pursuing an outside venture, but risks expropriation by the firm. We show that a weaker chance of expropriation, interpreted as the firm`s ability to protect internally developed intellectual property, can facilitate commercialization of innovations.

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1. Introduction

This paper offers a framework for studying the relationship between the strength of intellectual property (IP) enforcement and innovation incentives in firms. We use our model to disprove a common misconception — that weak IP protection necessarily hinders innovation. Our model consists of a firm and one or more employees. While working for the firm, an employee may come up with an innovative idea. We focus on ideas that require low start-up capital (e.g., computer software). Initially, the employee decides whether or not to pursue this idea. An employee who decides to pursue an idea may do so either in or outside of the firm. When pursuing an idea outside of the firm, the employee maintains control of the idea and has a first-mover advantage, but faces several hurdles. In particular, securing outside resources is a costly process with an uncertain outcome, and it can diminish potential proceeds from a successful innovation.

If the employee chooses instead to pursue the idea within the firm, he faces a tradeoff. On the one hand, internal development may be less costly due to existing infrastructures and development platforms. On the other, developing internally reveals some information about the idea to the firm. The firm, in turn, may be able to replicate the development process without the employee's expertise. Moreover, the firm can more credibly claim ownership over the innovation, as it was developed internally using its facilities. After internal development takes place, the firm and the employee negotiate over the surplus from the innovation. If they fail to reach an agreement, each can independently attempt to bring the innovation to market; if the employee succeeds, the firm can attempt to enforce its ownership and expropriate any proceeds from the innovation.

Using the above model, we are able to generate predictions regarding how the strength of IP enforcement interacts with the incentive to innovate within a firm. We find that weak enforcement can help facilitate innovation. Indeed, some of the most innovative industries of the last forty years, including computer software and hardware, have historically had weak IP protection (Bessen and Maskin, 2009).

This paper is related to a growing literature on start-ups, spinoffs, and the incentive to become an entrepreneur. Up until recently, studies exploring the interaction between IP protection and innovation incentives focused primarily on comparing two extremes — one where infringement always goes unpunished, and one where infringement is always deterred (Krasteva, 2011). See Klepper (2009) for a recent survey. Instead of guaranteed enforcement, we follow recent works in employing a probability of punishment as a measure of the strength of enforcement (Anton and Yao, 2004, 2007; Farrell and Shapiro, 2008; Krasteva, 2011).[1]

Related to our work, Anton and Yao (1995) show that in markets where innovation requires little start-up capital and where there is no IP enforcement, employees may

[1]This modeling approach is also appropriate for emerging economies where a limited amount of IP protection may be offered. Although emerging economies have worked to strengthen their market mechanisms through liberalization, stabilization, and the encouragement of private enterprise, the development of legal infrastructures has been relatively slow (EBRD, 1998). While it had been argued that weak enforcement of IP rights constituted a major impediment to investment in innovation (Devlin et al., 1998; Estrin and Wright, 1999; Hossiksson et al., 2000; Li and Atuahene-Gima, 2001; FTC, 2003), prior work has failed to empirically establish a strong positive relationship (Kortum and Lerner, 1999; Hall and Ziedonis, 2001; Sakakibara and Branstetter, 2001; Noel and Schankerman, 2006; Bessen and Hunt, 2007). One such example is Israel, where innovative activity has increased substantially during 1990-2000 despite relatively weak enforcement (Trajtenberg, 2001, WIPO, 2004).

seek to form start-ups even when joint profits from internal development are greater. Our model is different in several respects. First, we allow for the full spectrum of the strength of IP enforcement. Second, the employee in our model benefits from revealing an idea to the firm by being able to develop the idea at a lower cost. Third, we abstract from a common knowledge *ex-ante* probability of an employee coming up with an idea. In contrast to Anton and Yao (1995), we find that weaker enforcement can actually lead to more ideas being developed within the firm. Also related to our work, Bessen and Maskin (2009) show that when innovations are sequential and complementary, stronger IP protection can discourage future innovation. Their model consists of firms choosing whether or not to undertake R&D to discover and develop an idea that may be imitated by a competitor. Krasteva (2011) studies a related model of innovation where a firm takes into account potential imitation from a competitor when it chooses its investment in innovative activity. She finds that investment in innovation is maximized for intermediate levels of IP protection. Our analysis is complementary to these works, as we show that there is a stronger incentive to pursue innovations given weaker enforcement. However, our findings are obtained in the context of an employee innovating within a firm, as in Anton and Yao (1995). Employees in our model do not actively seek to discover new ideas — they stumble upon them. Moreover, whether or not to pursue new ideas, and whether to do so using the facilities of the employing firm, is a paramount decision for employees in our model.

We begin by formally setting up the model and giving expected payoffs when an innovation is pursued outside of the firm in Section 2. Section 3 solves the final stage of the game following internal development, whereas Section 4 solves for the expected payoffs in the previous stage after negotiations between the employee and the firm. Section 5 characterizes the equilibrium and gives comparative static results, and Section 6 concludes.

2. Model

The model consists of a firm (F) and one or more employees (E) who are paid a competitive wage, w. While working at the firm, an employee may come up with an innovative idea. In line with the literature, we focus on ideas that require little start-up capital. An idea is characterized by the parameters (v, Ψ), where v denotes the expected net value of the innovation in terms of revenues less variable costs, and $\Psi = (\alpha, \beta, \gamma)$ is a triplet of probability parameters that represent the likelihood of a successful innovation, depending on the specific development environment, to be formalized shortly.

Initially, the employee decides whether to pursue the idea, and if so, how to go about pursuing it. As the employee already has access to the firm's facilities, pursuing an idea within the firm has the benefit of more accessible infrastructure. If the employee instead chooses to pursue an idea as a start-up outside of the firm, we assume that the he is able to secure outside resources and succeed in bringing the innovation to market with probability β. In addition, a cost of c_O is associated with outside development. As the loss of a wage can already be captured in the cost c_O, we normalize the employee's competitive wage to 0 with no loss of generality. Outside development is thus profitable to the employee whenever $\beta v - c_O \geq 0$.

Internal development has added layers of complexity. The employee incurs a cost c_I for internal development, where $c_I < c_O$ signifies that development is less costly within the firm. However, given a successful internal development, the firm becomes more familiar with the innovation and may be able to replicate its development without the employee's expertise. The probability that the firm succeeds in this production process without the employee is given by γ. Hence, γ represents the imitability of the development process (for $\gamma \to 0$, the employee's knowledge about the innovation is indispensable in production).[2]

If the employee and the firm cooperate to produce jointly, they succeed with probability α, such that $\alpha > \max\{\beta, \gamma\}$ holds, whereby joint production is more likely to succeed than an individual attempt. If the employee is not involved in the firm's production, he can attempt to surpass two hurdles to produce externally. First, the employee must secure outside support and is only successful in doing so with probability β.[3] Hence, by developing internally, the employee is able to avoid incurring the cost $c_O - c_I$. Second, the firm can claim ownership over the innovation, as it was developed using its facilities. However, since the enforcement of IP ownership is imperfect, we let s denote the probability that the firm appropriates any rents from the innovation that are generated (externally) by the employee. Here, s represents the strength of IP protection.[4] To focus on a worst-case scenario in terms of the impact of imperfect protection on innovation, we assume that the cost of IP litigation is negligible. If IP ownership is not enforced, and if both parties successfully produce, we assume that competition between the firm and the employee dissipates any proceeds from the innovation.[5]

After internal development takes place, the firm and the employee negotiate over how to distribute any potential proceeds from the innovation, where their outside options are determined from the above. We model this stage using a reduced-form Nash Bargaining game, where, for technical simplicity, the two parties have equal bargaining powers (the results go through with different bargaining powers). If the firm and the employee fail to reach an agreement, each party can independently attempt to bring the innovation to market; if the employee succeeds, the firm can attempt to enforce its ownership and expropriate any proceeds from the innovation.

The timeline of the game is as follows.

(i) An employee comes up with an idea and decides whether to pursue it externally, internally, or to ignore it.

(ii) If the employee decides to develop the idea externally, he leaves the firm and has a chance to successfully develop the innovation.

(iii) If the employee chooses to develop the idea internally, the firm and the employee negotiate over the expected proceeds.

(iv) If an agreement is not reached, the firm and the employee can each attempt production, and the realization of a potential IP litigation takes place. If an agreement is reached, the firm and the employee jointly attempt production.

We are seeking the Subgame Perfect Nash Equilibrium (SPNE) of the game, for which we solve using backward induction. The subgame in which the employee devel-

[2] In a broader model, γ can also represent the extent to which information leaks to the firm.

[3] We assume that the employee does not incur the cost c_O in this case, as development already took place. All of the results go through when the employee incurs some cost, as long as this cost is lower than c_I.

[4] The parameter s can also be used to factor in a firm's reputation for enforcing its IP ownership.

[5] All of the results go through if the total proceeds from the innovation are not completely dissipated under competition but instead reduced to a level lower than the proceeds obtained when a single party produces.

ops and produces the innovation externally results in expected payoffs of $\pi_e^o = \beta v - c_O$ for the employee and $\pi_f^o = 0$ for the firm.

3. Disagreement Subgame

If the employee decides to develop the idea internally, he anticipates having to negotiate with the firm. In particular, after internal development takes place, as the firm becomes informed of the innovation, the two parties negotiate over any anticipated proceeds.[6] In order to determine the conditions under which an agreement takes place, we first characterize their disagreement payoffs.

If the firm and the employee fail to agree, the two parties independently decide whether to pursue production. This is modeled via a simultaneous game. Each party's expected payoff from production depends on the choice of the competitor. Figure 1 depicts the normal form of this game, where π_e^d and π_f^d give expected disagreement payoffs for the employee and the firm, respectively.

F \ E	Produce	Not Produce
Produce	$\pi_f^d = \gamma(1-\beta)v + (1-\gamma)\beta sv$ $\pi_e^d = \beta(1-\gamma)(1-s)v$	$\pi_f^d = \gamma v$ $\pi_e^d = 0$
Not Produce	$\pi_f^d = \beta sv$ $\pi_e^d = \beta(1-s)v$	$\pi_f^d = 0$ $\pi_e^d = 0$

Figure 1: Disagreement subgame

In this subgame, the employee has a (weakly) dominant strategy to attempt production. The firm, however, would choose to produce only when $\beta(1+s) \leq 1$, i.e., when enforcement and/or outside support are low. The intuition for this is simple. By attempting production, the firm runs the risk of destroying the proceeds from the innovation via competition — proceeds that it can try to capture via IP litigation. If the chances of capturing these proceeds by enforcing its IP are sufficiently high, and/or the employee is very likely to succeed in outside production, the firm would choose to forego its production attempt. The firm chooses to do so in order not to dissipate the proceeds from the innovation by competing with the employee's outside venture. We capture the inequality determining the firm's strategy in this subgame in the following condition.

Condition 1. *Let $(C1)$ denote the condition under which enforcement and/or outside support are sufficiently low such that the firm pursues production in the case of disagreement, i.e., $\beta(1+s) \leq 1$. Let $!(C1)$ denote the opposite, i.e., where $\beta(1+s) > 1$.*

4. Negotiation Subgame

In this stage of the game, the firm and the employee negotiate over how to divide the proceeds from the innovation. As mentioned in Section 2, we use a simple Nash-

[6] The qualitative nature of the results is unchanged if the firm only obtains partial information about the innovation after internal development takes place, as long as this information gives the firm some chance of bringing the innovation to market, as represented by γ.

bargaining solution to model this stage, where the firm and the employee equally split the surplus (if one exists) from joint production relative to producing independently. Whether the firm and the employee reach an agreement (i.e., whether a surplus exists) depends on the strength of IP protection, as represented by s,[7] the likelihood of success given a joint attempt, α, and the likelihood of each party succeeding independently, as given by β for the employee and by γ for the firm.

Lemma 1. *Given internal development, under $(C1)$, an agreement is reached if $\gamma + \beta - 2\gamma\beta \leq \alpha$. Under $!(C1)$, an agreement is always reached.*

Proof. The total surplus from agreement is given by αv. The total profit from disagreement under $(C1)$ is given by $\gamma(1-\beta)v + (1-\gamma)\beta sv + \beta(1-\gamma)(1-s)v$. The agreement surplus is greater than the disagreement surplus if $\gamma + \beta - 2\gamma\beta \leq \alpha$. If $(C1)$ does not hold, the sum of the disagreement payoffs is given by βv, always lower than the agreement surplus, αv, as $\beta < \alpha$. □

The intuition for this result is the following. Under $(C1)$, since both the firm and the employee attempt production, some of the expected proceeds from the innovation are dissipated due to potential competition, should both the firm and the employee succeed in their production attempts. However, since there are two independent attempts at production, the chances of exactly one party successfully producing may be higher than the likelihood of success under joint production. Under $!(C1)$, however, the surplus from pursuing joint production is always greater, since the probability of success, α, is higher. This, in turn, encourages the parties to reach an agreement. In other words, if $(C1)$ does not hold, joint production dominates because the employee suffers from a diminished chance of success should he choose to attempt production on his own.

If an agreement is reached under $(C1)$, the additional surplus from an agreement is given by $(\alpha-(\gamma+\beta)+2\gamma\beta)v$. Under $!(C1)$, it is given by $(\alpha-\beta)v$. When an agreement is reached, this surplus is divided between the firm and the employee. We summarize individual payoffs in the following proposition, where π_e^i and π_f^i give expected payoffs following internal development for the employee and the firm, respectively.

Proposition 1. *Under $(C1)$, if $\gamma+\beta-2\gamma\beta \leq \alpha$, the employee's expected payoff from internal development is given by $\pi_e^i = \frac{1}{2}(\alpha+\beta-\gamma-2\beta s(1-\gamma))v - c_I$, and the firm's expected profit is given by $\pi_f^i = \frac{1}{2}(\alpha-\beta+\gamma+2\beta s(1-\gamma))v$; if $\gamma+\beta-2\gamma\beta > \alpha$, they are given by $\pi_e^i = \beta(1-\gamma)(1-s)v - c_I$ and $\pi_f^i = \gamma(1-\beta)v + (1-\gamma)\beta sv$. Under $!(C1)$, expected payoffs are given by $\pi_e^i = \frac{1}{2}(\alpha+\beta(1-2s))v - c_I$ and $\pi_f^i = \frac{1}{2}(\alpha-\beta(1-2s))v$ for the employee and firm, respectively.*

The next section folds the game back to its initial stage, where an employee decides whether to pursue an idea internally, externally, or to ignore it altogether.

5. Equilibrium Characterization

The following proposition characterizes when an employee will choose to develop a new idea inside the firm.

[7]The strength of protection comes into play in determining whether or not condition $(C1)$ holds.

Proposition 2. *An employee will choose to develop a new idea inside the firm when a combination of the following holds: (i) The probability of securing outside support is low, (ii) enforcement is weak, (iii) the cost of development is low, and, under $(C1)$, (iv) the degree of imitability is low.*

- *Under $(C1)$, if $\gamma+\beta-2\gamma\beta \leq \alpha$, this is satisfied when $\frac{1}{2}(\beta+\gamma+2\beta s(1-\gamma)-\alpha)v \leq c_O - c_I$ and $\frac{1}{2}(\alpha+\beta-\gamma-2\beta s(1-\gamma))v > c_I$. If $\gamma+\beta-2\gamma\beta > \alpha$, it is satisfied when $\beta(\gamma+s(1-\gamma))v \leq c_O - c_I$ and $\beta(1-\gamma)(1-s)v > c_I$.*
- *Under $!(C1)$, it is satisfied when $\frac{1}{2}(\beta(1+s)-\alpha)v \leq c_O - c_I$ and $\frac{1}{2}(\alpha+\beta(1-2s))v > c_I$.*

Proof. We have determined the employee's expected payoff from outside development to be $\pi_e^o = \beta v - c_O$, whereas his expected payoff from internal development is given by Proposition 1. Comparing the employee's payoffs and requiring the payoff from internal development to be non-negative gives the result. □

Intuitively, the employee chooses internal development whenever it is profitable, and, the expected loss due to revealing his idea to the firm is lower than the expected gain from reduced development costs, as given by $c_O - c_I$.

Since $(C1)$ requires that $\beta(1+s) \leq 1$, it follows that the condition for internal development to take place is stricter under $(C1)$. The intuition for this is easily understood. Since the employee anticipates the firm would also make an attempt at production and thus possibly constitute a competitor, the employee would only pursue internal development if the likelihood of the firm successfully replicating the development process is low.

From the firm's perspective, for a given idea, an increased level of protection (i.e., a higher s) results in a higher profit and benefits the firm as long as the employee still chooses to develop the idea internally. However, an increased level of protection would result in fewer ideas being funneled though internal development overall, and, depending on the distribution of new ideas, could also lead to lower expected profits.

Using the conditions in Proposition 2, we obtain the following comparative statics results with respect to the strength of enforcement parameter, s:

Proposition 3. *Given a randomly drawn innovation idea with parameters (v, Ψ), if the enforcement level, s, is increased, then:*

1. *Fewer innovations will be developed, both internally and overall.*
2. *Innovations that are developed internally are likely be less imitable (i.e., lower γ).*
3. *A lower availability of new venture funding (i.e., a lower β) has a moderating effect on an increase in enforcement, s, in terms of which innovations are developed internally.*
4. *A higher level of support for internal innovation (i.e., a lower c_I) results in more innovations overall and has a moderating effect on an increase in enforcement.*

For Part (1) of Proposition 3, we observe that all three inequalities for internal development in Proposition 2 are weakened by an increase in s. Moreover, since external development is costly, the employee's preferring outside development does not guarantee his pursuit of the innovation. In particular, since $c_O > c_I$, it may be the case that $\beta v \leq c_O$ holds while $\alpha v \geq c_I$. In other words, the employee would choose to forego innovating although it is socially efficient to do so (i.e., forego development although the innovations generate positive overall returns).

For Part (2), under ($C1$), the inequalities in Proposition 2 for internal development are less binding as γ decreases. Moreover, more innovations are likely to fall under condition ($C1$) as s increases. Similarly, for Parts (3) and (4), we observe that all three inequalities in Proposition 2 are less binding as β and c_I are reduced. Moreover, as c_I is reduced, more innovations are profitable for the employee to pursue.

The results from Proposition 3 go counter to intuition. Specifically, while it may seem intuitive to conclude that a stronger level of property rights enforcement would foster innovation, our findings point out that the opposite may hold in the context of employees innovating within a firm. The reasoning is simple. Innovations within firms, especially in sectors of high-paced innovation, such as technology, is often conducted by individual employees rather than by the firm as a collective entity with a singular purpose. Employees pursue their own objectives, and as support for innovation becomes more accessible, their incentives for pursuing innovations are increased. Stronger IP protection can actually work to diminish the incentive to innovate for individual employees, as it reduces their expected returns from internal development. Effectively, development costs are increased, as more innovations are pursued externally by entrepreneurs forgoing more accessible internal resources, which can result in fewer innovations being pursued overall.

6. Concluding Remarks

In this paper, we examined the relationship between firm innovation and the imperfect enforcement of IP ownership. Our first step was to model a process of innovation within firms. We constructed a model that allowed us to disentangle the payoff-motivated tradeoffs at the employee level. We then studied how the strength of enforcement interacted with the incentive to innovate. We found that weak enforcement can help facilitate innovation in firms. The intuition is simple. A stronger level of IP protection reduces the incentive to innovate for individual employees, as it diminishes their expected returns. Subsequently, some innovations with positive expected returns will be ignored.

Several caveats to our analysis are in order. First, we did not consider the impact of decreasing IP protection on entrepreneurs who develop and produce outside of firms (i.e., who own the IP). Our analysis distinguished an employee having a first-mover advantage by developing and producing externally versus facing potential litigation by developing inside the firm. Indeed, many start-ups do not possess the capability to litigate against established firms, and their primary forms of protection against competition are secrecy, moving first, and moving fast. In such cases, our analysis applies, as we capture the tradeoff between more accessible resources inside a firm and a first-mover advantage outside. Second, our analysis did not take into account innovations by entrepreneurs who do not currently (and perhaps do not wish to) work within established firms, who may be hurt by weaker IP protection. While that may be the case, our findings show that not all types of entrepreneurship are necessarily hindered by weaker protection. In fact, evidence indicates that innovations developed by start-ups were often conceived by former employees of established firms (Bhide, 1994). Third, we did not assign employees in our model any intrinsic utility from becoming an entrepreneur, and it is plausible that this utility is non-negligible. However, our model can be readily extended to incorporate such considerations, provided that the monetary value associated with this utility does not exceed the cost saving from developing internally, as given by $c_O - c_I$.

Finally, since we focused on innovations which require little start-up capital, such as computer software, the probability of success of an employee's new venture did not depend on the strength of IP protection. In settings where innovations require significant start-up capital, the situation is more complex. In such settings, β can be interpreted as the product of the likelihoods of obtaining outside support and succeeding in bringing the innovation to market.[8] It is indeed possible (and likely the case) that the likelihood of obtaining outside support is then impacted by the strength of IP protection,[9] though whether it is monotonically increasing in the strength of protection is unclear – in fact, it can very well be non-monotonic (Bessen and Maskin, 2009; Krasteva, 2011). The availability of new venture support would also be impacted by the required amount of start-up capital. In particular, in industries where the required amount of start-up capital is significant, such as pharmaceuticals, stronger protection may be needed to encourage investment in innovative activity. At the same time, since innovations developed by start-ups are often conceived by former employees (Bhide, 1994), while such innovations may eventually be produced outside of the firm, the initial development can often occur internally. In these cases, as stronger protection reduces the expected proceeds from taking such innovations outside of firms, the incentive for a third party to invest in them would diminish. Hence, it is not immediately clear how new venture investment behaves in response to changing industry parameters, and it is likely dependent on both the strength of protection and the requisite start-up capital.[10] From a policy perspective, then, the extent of IP protection should be industry specific and periodically adjusted to foster innovation under the current set of industry parameters.

We leave the possibility of innovations with varying amounts of start-up capital, where β is engodenized, for future work. However, one observation is in order: If β_D denotes the probability of obtaining external support *after* internal development (which can be different from the probability of obtaining external support prior to development), all of the results go through as long as β_D is decreasing in the strength of IP protection. A clear direction for future work is therefore to consider a larger set of innovations and to endogenize the availability of new venture support. One could also apply the model to the study of optimal patenting policies, determining optimal patent breadth and length to maximize innovation both in and out of established firms. Another direction for future work is to empirically test our predictions for firm-employee innovation over time, and across industries within the same time frame, calibrating the model with industry-specific parameters.

[8]With a small extension to the model, β can also incorporate the share of the proceedings that are lost to the employee due to securing outside investment.

[9]Foreign investment is likely to be particularly impacted by a complete lack of enforcement (Hossiksson et al., 2000).

[10]Our results readily extend to these more complex settings over regions of IP enforcement levels where the likelihood of obtaining outside support is decreasing in the strength of protection.

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