Management of Knowledge Workers*

Hans K. Hvide and Eirik G. Kristiansen†

March 30, 2007

Abstract

We study how complementarities and intellectual property rights affect the management of knowledge workers. The main results relay when a firm will wish to sue workers that leave with innovative ideas, and the effects of complementary assets on wages and on worker initiative. We argue that firms strongly protected by property rights may not sue leaving workers in order to motivate effort, while firms weakly protected by complementary assets must sue in order to obtain positive profits. Firms with more complementary assets pay higher wages (and have lower turnover), but such higher pay has a detrimental effect on worker initiative. Our analysis suggests that strengthening firms' property rights protection reduces turnover costs but weakens worker initiative.

Keywords: Entrepreneurship, Innovation, IPP, Litigation, Personnel economics, R&D, Start-ups.

*Thanks to Amar Bhide, Keith Crocker (the Editor), Eddie Lazear, Josh Lerner, Lasse Lien, Jim March, Suzanne Scotchmer and two referees for comments, and to the Norwegian Research Council (KUNI program) for financial support.

†Hvide: University of Aberdeen, Business School. Kristiansen: Norwegian School of Economics and Business. Hvide is also affiliated with CEPR, IZA and NHH, and Kristiansen with the Norwegian Central Bank. Email: hans.hvide@abdn.ac.uk, eirik.kristiansen@nhh.no.

To make knowledge-work productive will be the great management task of this century, just as to make manual work productive was the great management task of the last century (Peter Drucker, 1969, p.290).

1 Introduction

Knowledge workers make up a significant fraction of the workforce in advanced economies (some estimates loom as high as 25-30%). Their expertise determines the success of countless organizations around the world, but still we have limited insight on the management of such workers.[1] This paper studies an environment where worker initiative stems from the possibility of leaving its employer carrying valuable ideas, and firms are imperfectly protected by complementary assets and property rights. Our analysis addresses two questions. When will a firm take legal action and sue its leaving workers? How do complementary assets and property rights influence a firm's wage policy and worker initiative?

The crux of the paper is twofold. We argue that a firm weakly protected by complementary assets should sue its leaving workers, while a firm strongly protected by property rights may not. A firm weakly protected by complementary assets must sue in order to avoid having only unproductive workers stay on in the firm. A strongly protected firm may not sue because suing would eliminate worker initiative. Second, we argue that firms with more complementary assets should pay higher wages, and will as a result experience less worker initiative. The intuition is that a firm with more complementary assets has a higher marginal value from workers staying on, and will therefore pay higher wages in order to keep more workers. However, such higher pay will serve as a cushion that weakens worker initiative.

In the model, firms are exposed to both moral hazard in that workers exert unobservable effort to generate ideas, and adverse selection in that workers observe their ideas privately. After a worker has generated an idea, the firm offers a continuation wage which the worker may accept and stay on in the firm, or reject and start up his own business. If

[1] See the January 2006 survey of the Economist, Roberts (2004), or Neef (1999) for evidence on the importance of knowledge workers.

the worker leaves, the firm may sue the worker. Complementarities play a role in determining the value of the idea to the firm. Property rights play a role in determining how likely it is that the firm wins a litigation case against the worker.

The worker's motivation to exert effort stems from being able to capture a fraction of the value of the idea if leaving. The worker has stronger incentives to exert effort if he expects the firm not to sue, since this fraction then becomes larger. The firm's litigation policy therefore balances the benefits from more motivated workers with the costs from more workers leaving. At a casual level, this trade-off accords with the personnel policy at Hewlett Packard, which in addition to encouraging workers to start up their own companies had a reputation for the employees being highly motivated.

We find that a firm strongly protected by complementary assets and by strong property rights may not sue leaving workers. The reason is that suing would then be a "too powerful" instrument and ruin worker initiative. Conversely, we find that a firm not protected by complementary assets must sue in order to get positive profits. The intuition is that if the firm does not have complementary assets, not suing will lead to adverse selection where only workers not worth the wage they are paid will stay on in the firm.

Our analysis suggests that firms more strongly protected by complementarities pay higher wages, has less turnover and has less motivated workers. Stronger complementarities imply that a given idea has a higher value inside the firm, and the firm decreases turnover by paying more. Lower turnover implies less motivated workers, because the entrepreneurial option becomes less attractive relative to staying on in the firm. If we assume that larger firms have stronger complementarities, these findings are consistent with evidence that larger firms pay higher wages (see e.g., Fox (2004) for an overview) and have lower turnover (Even & MacPherson (1996) and Kim & Marschke (2005)).

Finally, our analysis suggests that weakened property rights protection increases worker initiative but wastes synergies. Received literature (e.g., Scotchmer (2004)) argues that intellectual property rights should be strong when ex-ante effects (on firms' R&D investments) are important relative to ex-post effects (on the use of innovations). Our analysis complements the existing literature by investigating how the strength of the firm's intellectual property rights influences workers' motivation to innovate. Firms that are strongly protected may suffer from less motivated workers but benefit from reduced turnover and

less waste of synergies. By treating the firm as a unit, the existing literature has not accommodated this trade-off.

The paper is structured as follows. The next subsection discusses related literature. The model and assumptions are presented in Section 2. Section 3 contains the analysis and Sections 4 discusses out-of court settlement and profit sharing arrangement between the worker and firm. Section 5 concludes and the Appendix contains the proofs.

1.1 Related literature

The empirical motivation for the paper comes from several sources. Bhide (2000) finds that 71% of entrepreneurs in his sample replicated or modified an idea encountered through previous employment, which echoes earlier findings by Cooper (1984). Kim & Marschke (2005) advocate that patenting can be seen as a protective measure against employees. Consistent with this idea, they find that firms located in industries with higher worker turnover rates patent more.[2] On the prevalence of workers leaving their employer, Stone (2002) reports that the number of court cases involving covenants not to compete and trade secrets has increased sharply over the last decades. Similar findings are reported by Lowry (1988). At a case level, Hewlett-Packard institutionalized a famous policy where workers were encouraged to leave and start up their own companies, often with ideas based in their employment at Hewlett-Packard.[3] On the other hand, in a much-publicized case where workers from the electronics company Cadence founded a company based on software programs and customer relations developed at Cadence, Cadence sued the workers and several of the previous employees received fines and prison sentences (Glynn & Mukherjee (2003)).[4] This anecdotal evidence is suggestive of heterogeneity in the suing policy of R&D intensive firms.

[2] A range of anecdotal evidence supports the idea that knowledge workers pose a threat to firms in addition to providing crucial inputs. A fascinating historical account is given by Fisk (2001). Oyer & Schaefer (2005) and Møen (2005) provide evidence that firms set wages in order to retain workers (rather than to motivate effort).

[3] The response of Dave Packard, one of the two founders of Hewlett-Packard, was, "Are we upset that they left us? On the contrary, Bill and I understand and respect their entrepreneurial spirit." (Packard, 1995)

[4] Among more well-known companies, Intel and Microsoft have a reputation for being uncooperative with leavers, and the same goes for a range of Route 128 companies as described by Saxenian (1994).

There are three branches of the literature that address related issues: the management of innovation, the economics of litigation, and the industrial economics of R&D. This paper differs from the existing literature in some important respects.

Pakes & Nitzan (1983) considers a moral hazard problem where firms have no formal property rights protection and workers can appropriate part of their output. Such appropriation provides workers with an incentive to provide effort. While our model shares this feature of Pakes-Nitzan, their paper does not consider workers having private information about output, which drives turnover in our model, nor the possibility of firms suing leaving workers.[5] In the incomplete contract setting of Aghion & Tirole (1994), the problem is how to allocate ownership to alleviate hold-up problems between a research unit and a customer. Their assumption that ownership rights over an invention are contractible eliminates most of the issues we are concerned about, in particular turnover.

Hellmann (2007) and Subramanian (2005) consider the multi-tasking problem that ensues if a worker can engage in "private activities" on the job with the intention of creating a start-up later. In contrast to these papers, we assume that the main problem from the firm's viewpoint is that workers leave with ideas generated through their legitimate work. These papers do not discuss the firm's incentives to litigate workers. Perhaps most closely related to our paper, Motta & Rønde (2003) analyzes how not to compete clauses influences the worker's provision of innovative effort. They show that a firm might prefer not to include such a covenant in the employment contract, in order to commit to reward the worker. In contrast to in our paper, they do not consider how the firm's behavior might be affected by strength of property rights protection or by complementary assets. Lewis & Yao (2003) shows that firms may choose an open research arrangement (open interaction with agents outside the firm) if this helps the firm in attracting workers. They do not consider workers' incentives to exert effort.

In Anton & Yao (1995) a worker privately discovers an idea and the authors study when the worker will leave the firm in order to develop the idea (start up) and when the worker together with the firm will develop the idea (spin-off). A worker leaves if he would

[5] The same holds for Kim & Marschke (2005). Hvide (2005) considers a Pakes-Nitzan type of model where workers have private information about the value of their idea. Hvide (2005) does not consider workers' effort decision, nor firms' suing decision.

be in a weak bargaining position by staying and sharing the idea with the firm. As in our analysis, Anton & Yao (1995) analyzes a setting where weak property rights restrict the firms ability to compensate the worker for ideas and this may lead to start-up activities. They do not consider the role of complementary assets or the firm's suing policy.

Anton & Yao (1994, 2002) asks how a privately informed inventor might sell an idea when formal property rights are non-existing. Anton & Yao (1994) argues that the threat of selling off the idea to a competitor may give the inventor some rents from bargaining with an incumbent firm, and Anton & Yao (2002) argues that a partial disclosure of the idea can be beneficial to the inventor.[6] We use the insight from Anton-Yao that an inventor may be reluctant to reveal the content of an idea to motivate our assumption that workers have private information about their innovations. In Section 4, we discuss mechanisms in which the worker can transmit his private information.

The incentives to litigate have been studied by several authors, e.g., Bebchuk (1984) and Reinganum & Wilde (1986) on pretrial negotiations, and Priest & Klein (1984) on the probability of succeeding in court. On empirical evidence, Siegelman & Waldfogel (1996) and Lanjouw & Lerner (1998) estimates a Priest-Klein model on data from litigation cases, and finds that intellectual property rights cases are relatively predictable but also quite hard to win (about 35% are ruled in favor of the plaintiff in the former sample).

According to Mansfield (1986) and Teece (1986) in many industries firms regard complementary assets, rather than property rights, as their main tool for protecting their innovations. The present paper is to our knowledge the first on how complementary assets affect the management of knowledge workers. Most of the industrial economics literature on R&D has considered the firm as a unit and examined how product market competition and patent policy jointly determine R&D investments (Scotchmer (2004) gives an overview). While this literature provides insight into how a firm's competitive environment stimulates investments in R&D, it has been unable to analyze how successful innovation depends on worker initiative.

[6] A related literature considers how to protect innovations from product-market competitors (see e.g., Anton & Yao (2004)). The underlying tension is that patents may give stronger formal rights but also disclose more about the innovation.

2 The model

There is one principal (owner) and one agent (worker). The agent has reservation utility $\bar{U} > 0$. At date 1, the agent is hired and paid an initial wage $F \geq 0$.[7] The worker then exerts effort e at a private cost $c(e)$, where $c(e)$ satisfies the standard conditions $c(0) = c'(0) = 0$ and $c''(e) > 0$. At date 2, an idea with stand-alone value x is realized, where $x = e + \epsilon$ and ϵ is a random variable with full support and distribution function $G(.)$.[8] The agent learns x, whereas the firm does not. The firm then offers a continuation wage $B \geq 0$ based on its conjecture about x. The agent accepts or rejects B. Accepting B means signing an extension of the employment contract, in which case the final payoffs become $\theta x - B$ to the firm and B to the agent, where $\theta \geq 1$. If the agent rejects, he quits the firm and develops a start-up based on x. The parameter θ reflects the gains from developing the idea inside the firm due to complementary assets (such as equipment, sales channels, or co-workers). These complementarities being weak correspond to θ close to 1, and strong complementarities correspond to $\theta >> 1$. Throughout, we assume that $G(.)$ is such that utility and profits are globally concave.[9]

The worker's payoff from leaving with the idea depends on whether the firm sues the worker at date 3 or not. At date 3, the idea has matured into something more "physical" (like technical drawings or a prototype) that - although its value is not verifiable - the court can transfer from the worker to the firm. If the firm does not sue, the final payoffs become 0 to the firm and x to the worker. If the firm sues, the payoffs depend on the court outcome. If the court rules in favor of the firm, the firm gets $\theta x - v$, where $v \geq 0$ is the cost of litigation. The worker gets zero. If the court rules in favor of the worker, the worker keeps the idea and develops it independently of the firm. The firm then gets $-v$ and the worker gets x. We assume that the litigation cost of the worker is zero (altering this assumption has no qualitative impact on the results since the worker would never

[7] Note that $F = 0$ reflects the realistic case where the firm pays the worker a low wage in the first period (although not a negative wage, which would VIOLATE THE LIMITED LIABILITY CONSTRAINT) but the worker has the chance of discovering a valuable innovation.

[8] The full-support assumption implies that ideas can have a negative value. If the support of the idea quality is positive ($\epsilon > 0$) then all our results continue to hold, and "negative profits" is replaced by "non-positive" profits in the proof of Proposition 1.

[9] GLOBAL CONCAVITY IS USED TO PROVE LEMMA 1, BUT IS NOT NECESSARY FOR OUR OTHER RESULTS, WHICH HOLD ALMOST EVERYWHERE (I.E., EXCEPT FOR AT ISOLATED POINTS).

initiate a court case).

As evidenced by a large legal literature (see e.g., Kim & Marschke, 2005, page 299, for references) firms and employees cannot easily contract around the problem of workers leaving with innovations, an important reason being that overly broad non-compete CLAUSES will be voided by courts. We therefore assume that enforcement by courts is probabilistic, in that the firm wins the litigation trial with probability $\phi \in [0, 1]$. A low (high) ϕ corresponds to a situation where the court enforcement is weak (strong). The idea that court outcomes are probabilistic has substantial empirical support, see e.g., Lemley & Shapiro (2005). We think of ϕ as partly being determined by industry characteristics such as difficulty in assessing the nature of early-stage innovations, and partly by legislation rules and practice. Stone (2002) discusses various aspects of the law of post-employment restraints and argues that the courts' enforcement of such restraints varies from state to state and even from case to case. For example, courts differ in their interpretation of whether negative knowledge qualifies as a trade secret (Stone, 2002, p. 756) or more generally in their emphasis of protection of firms' R&D investments versus the protection of free worker mobility and the right to start up a new company.

On the timing of moves, we assume that the firm commits to a deterministic (binary) litigation policy at date zero.[10] One way to justify commitment is that it is verifiable whether the worker leaves or not, and whether the firm sues, so that the firm can build a reputation for being tough or lenient with leavers. Another interpretation of commitment is that suing is contractible; committing not to sue could be to grant formal ownership rights up-front to the agent over the innovation (as in Aghion & Tirole, 1994).[11]

[10] We assume that the suing decision is binary for two reasons. First, writing a contract that specifies that the firm sues with a certain probability seems unrealistic. Second, since the event of workers leaving to form their own companies is likely to occur relatively infrequently, building a reputation for a probabilistic litigation policy seems unrealistic.

[11] Justifying commitment by reputation is not appropriate under all instances. For example, the firm could be too small or too young to have established a reputation. Or, in a richer modeling setup, there could be other reasons for turnover than "stealing" ideas, and it could be less clear to the environment whether the firm abstains from suing because the worker left without an idea or if the firm refrains from suing.

We expect the results under no-commitment to be different in some respects. Under no-commitment, the firm would sue more often (since there is no negative effect on effort from suing, in contrast to in the commitment case, see Lemma 1), and as a result effort will be lower than in the commitment case. We do not, however, expect no-commitment to change our comparative statics results (Proposition 2 and Proposition 3).

A key feature of our setup is that the firm cannot commit to pay the agent a wage conditional on idea quality. We believe that such lack of commitment is a reasonable benchmark since - in contrast to whether the worker leaves or not - the quality of the idea or even the worker pay will unlikely be observable to outsiders and co-workers. It could therefore be quite difficult for the firm to establish a reputation for paying workers according to the quality of their ideas. In Section 4, we discuss this issue in more detail.

An overview of the timing appears in Figure 1.

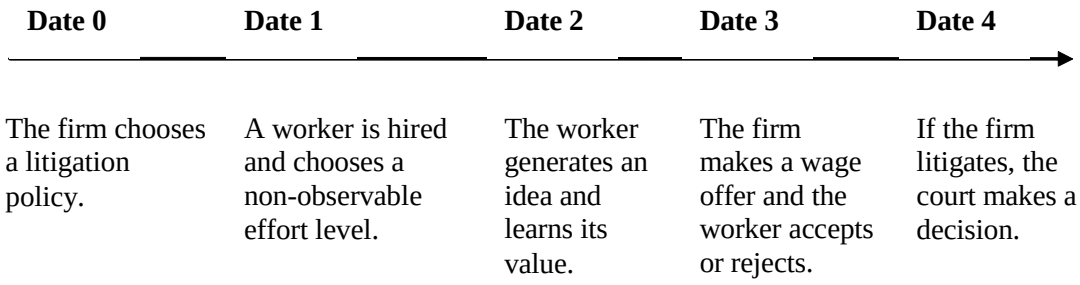

Figure 1: Timing

The basic trade-offs are as follows. The worker chooses an effort level trading off its private cost against a higher value of the idea if he becomes an entrepreneur. The firm sets a wage that trades off the gains from keeping better worker types (ideas) with the cost of paying more for all staying worker types. We focus on Perfect Bayesian equilibria (PBE). A combination of strategies is a PBE if a)the firm sets a wage and its suing policy optimally given its beliefs about effort, b)the worker anticipates the firm's behavior and chooses effort to maximize his utility, and c)the firm's conjecture about effort and the worker's conjecture about the wage setting are fulfilled on the equilibrium path.

3 Analysis

We solve the game by in backwards sequence examining the worker's leaving decision, the firm's wage offer, the worker's effort decision, and the firm's suing policy. Then we analyze the effects of changing the level of complementary assets (θ) and strength of property rights protection (ϕ).

3.1 Effort and wages

First we examine effort and wage setting in the subgame if the firm litigates. Then we examine the same variables in the subgame where the firm does not litigate.

When deciding whether to leave or not, the worker compares what he gets from staying, B, with the expected payoff from leaving and starting up his own company, denoted by U. Since the payoff from leaving increases in x (independently of whether the firm sues or not) the worker leaves if x exceeds some (unique) threshold value. We denote this threshold for z, i.e., $z = \{x : U = B\}$.

Case I. The firm litigates. The worker gets B if he stays in the firm, while the expected payoff from leaving equals $(1-\phi)x$. Hence $z = B/(1-\phi)$. For given B and e, the worker's expected utility equals,

$$U = \int_{-\infty}^{z-e} Bg(\epsilon)d\epsilon + (1-\phi)\int_{z-e}^{\infty}(e+\epsilon)g(\epsilon)d\epsilon - c(e). \tag{1}$$

The first integral is the worker's expected utility when staying ($x < z$) and the latter integral is the worker's utility if he leaves ($x > z$). Let us analyze the worker's effort decision. Suppose that the worker believes that the firm will offer B at date 3 (in equilibrium his conjecture is fulfilled). The marginal utility from exerting effort equals,

$$\begin{aligned} U_e &= -Bg(z-e) + (1-\phi)(e+z-e)g(z-e) + (1-\phi)\int_{z-e}^{\infty} g(\epsilon)d\epsilon - c'(e) \qquad (2)\\ &= -[(1-\phi)z - B]g(z-e) + (1-\phi)[1-G(z-e)] - c'(e). \end{aligned}$$

Since $B = z(1-\phi)$, the first term cancels and the optimal effort choice, e^*, is implicitly defined by,[12]

$$(1-\phi)\left(1-G\left(z-e^*\right)\right) - c'(e^*) = 0. \tag{3}$$

The first term represents the marginal gain from effort while the second term reflects the marginal cost. Since $1-G(.)$ equals the probability that the agent starts up his own

[12] Second order condition $U_{ee} = (1-\phi)\,g(z-e^*) - c''(e^*) < 0$.

company, we see that the agent's motivation to exert effort stems from the possibility of becoming an entrepreneur. All other equal, the worker will be more strongly motivated if property rights are weak, or if he expects a subsequent low wage offer to be made by the firm. The first best level of effort obtains for $c'(e) = 1$. A high ϕ or a low expected wage both contribute to make the worker's effort inefficiently low.

Let us now turn to the firm's choice of B. For given (e, B) the firm's profit equals

$$\Pi = \int_{-\infty}^{z-e} (\theta(e+\epsilon) - B)g(\epsilon)d\epsilon + \int_{z-e}^{\infty} (\phi\theta(e+\epsilon) - v)g(\epsilon)d\epsilon - F. \tag{4}$$

The first integral is the firm's profit from worker types that stay, and the second integral is the firm's profits from suing worker types that leave. Suppose that the firm believes that the worker chooses effort level equal to e (in equilibrium this conjecture is fulfilled). Taking z as the firm's choice variable, the marginal profit equals,

$$\begin{aligned} \Pi_z &= (\theta z - B)g(z-e) - \int_{-\infty}^{z-e} \frac{\partial B}{\partial z} g(\epsilon)d\epsilon - (\phi\theta z - v)g(z-e) \\ &= (\theta z - B)g(z-e) - (1-\phi)G(z-e) - (\phi\theta z - v)g(z-e) \\ &= [z(\theta-1)(1-\phi) + v]g(z-e) - (1-\phi)G(z-e). \end{aligned} \tag{5}$$

This equation reflects the firm's trade-off when setting a wage offer. An increased wage means that the firm keeps more worker types (the first term), but must also pay more to all types that stay (the second term). We see that a higher θ increases the gain from keeping the marginal worker type. A higher ϕ decreases the gain from keeping the marginal worker type (since the firm gets more from suing) and decreases the wage increase necessary to keep the marginal worker type. The optimal z, denoted by z^*, is implicitly defined by $\Pi_z = 0$.

Case II. The firm does not litigate. If the firm does not litigate, the worker's payoff from leaving equals x. Hence $z = B$. It follows from the same type of derivation as in Case I that the optimal level of effort, e^*, solves,

$$1 - G\left(z - e^*\right) - c'(e^*) = 0. \tag{6}$$

Just as in Case I, the agent's incentive to exert effort stems from the possibility of later becoming an entrepreneur. Since the worker keeps a higher fraction of value upon leaving than in Case I, the worker's incentives to exert effort are stronger (for given z) in Case II than in Case I. The profit given not suing equals

$$\Pi = \int_{-\infty}^{z-e} (\theta(e+\epsilon) - B)g(\epsilon)d\epsilon - F. \tag{7}$$

The firm's marginal profits become,

$$\begin{aligned} \Pi_z &= (\theta z - B)g(z-e) - \int_{-\infty}^{z-e} \frac{\partial B}{\partial z} g(\epsilon)d\epsilon \\ &= (\theta z - B)g(z-e) - G(z-e) \\ &= z(\theta - 1)g(z-e) - G(z-e). \end{aligned} \tag{8}$$

As in Case I, an increased wage means that the firm keeps more worker types (the first term), but must also pay more to all types that stay (the second term). A higher θ increases the gain from keeping the marginal worker type, and ϕ has no effect on the optimal wage policy. The optimal z, denoted by z^*, is implicitly defined through setting $\Pi_z = 0$.

3.2 Suing policy

Having characterized the optimal leaving and effort decision by the worker, and the optimal wage offer by the firm, let us now examine the firm's choice of suing policy. We first clarify the trade-off involved when choosing a suing policy. The following result follows from a direct comparison of the suing and no-suing subgames.

Lemma 1 *Fix θ and ϕ. Effort is lower if the firm sues than if the firm does not sue.*

Proof. See Appendix. ■

Lemma 1 clarifies the firm's trade-off the when deciding upon a suing policy. Suing ensures that the firm gets a piece of the cake if the worker leaves, but also reduces the size of the cake since effort decreases. To understand this result, consider Figure 2 which

illustrates the worker's best effort response function, $e^*(z;.)$ and the employer's best response function $z^*(e;.)$.

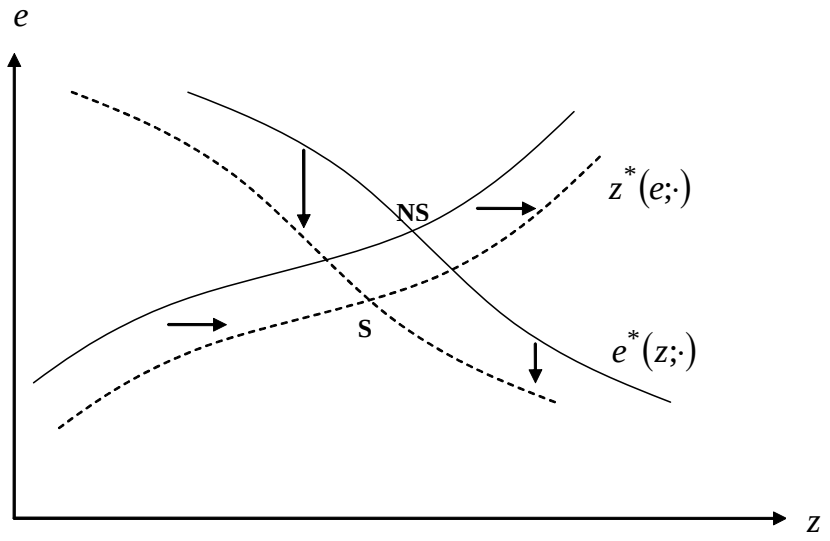

Figure 2: Effects from the firm deciding to sue leaving workers.

$e^*(z;.)$ slopes downward because a higher expected wage offer means that the worker becomes less motivated. $z^*(e;.)$ slopes upward because a higher e means that it will be more attractive to keep the marginal worker type. The unique equilibrium given no suing is given by the intersection of the two solid lines.

If the firm sues, the worker's marginal gain from effort (for a given conjecture about z) is less than if the firm does not sue, since his share of the cake becomes smaller. This reduction in the incentives to supply effort is depicted by the vertical arrows in Figure 2. The firm, on the other hand, will with suing have a higher marginal gain from raising z than under no suing (for a given conjecture about e) since he now avoids the suing costs. This increase in the incentives to pay the agent is depicted by the horizontal arrows in Figure 2. Both effects work in the direction of a lower effort when moving from a no-suing to a suing regime, as depicted by the move from NS to S in Figure 2. The economic implication is that the firm faces a clear trade-off when choosing a suing policy: suing gives weaker incentives for the worker to leave but also weaker incentives to exert effort.

The net effect on z from suing is ambiguous.[13] From Figure 2 we see that if the worker's effort only weakly responds to changes in the value of their outside option ($e^*(z;.)$ is flat) then the effect on $z^*(e;.)$ will dominate and, consequently, z decreases if the firm practices a lenient suing policy towards leavers.

The firm's suing decision. We now investigate how θ and ϕ affect the suing decision.

Proposition 1 *(i)A firm not protected by complementary assets ($\theta = 1$) must sue its leaving workers to get positive profits.(ii)A firm strongly protected by property rights ($\phi \approx 1$) may not sue its leaving workers.*

Proof. See Appendix. ■

If a firm not protected by complementary assets does not sue, adverse selection implies negative profits. For any continuation wage level, the firm will only keep worker types with ideas less valuable than the offered wage. In contrast, a firm that is strongly protected through complementarities and intellectual property rights may increase its profit by relinquish its intellectual property rights and not sue. The intuition is simple: a no-suing policy improves the worker's outside option and increases effort. With complementarities, the positive effect on profits from increased effort can be stronger than the negative effect on profits from not suing the leavers. Given this argument, our interpretation of HP's personnel policy is that it was well protected by property rights or by complementary assets, so well that suing leaving workers would seriously influence worker initiative.

3.3 Complementary assets

Let us now evaluate how worker initiative and wages change if the firm holds more complementary assets. The following result holds independently of the firm's suing decision.

Proposition 2 *If the firm holds more complementary assets, then*
i) wages are higher,

[13] The effect on wage setting is ambiguous as well. By suing leaving workers, the firm finds it easier to keep workers by increasing the wage level slightly (the marginal effect on z from an increase in wage B is increased). On the other hand, the firm can reduce its wage offer because it captures value from leaving ideas. Therefore, depending on parameter values of the underlying distribution functions and cost of effort function, suing and wages can be complementary or substitute instruments for the firm when it tries to keep its workers.

ii) effort is lower, and

iii) turnover is lower.

Proof. See Appendix. ■

Figure 3 illustrates how an increase in the amount of complementary assets changes the equilibrium outcome.

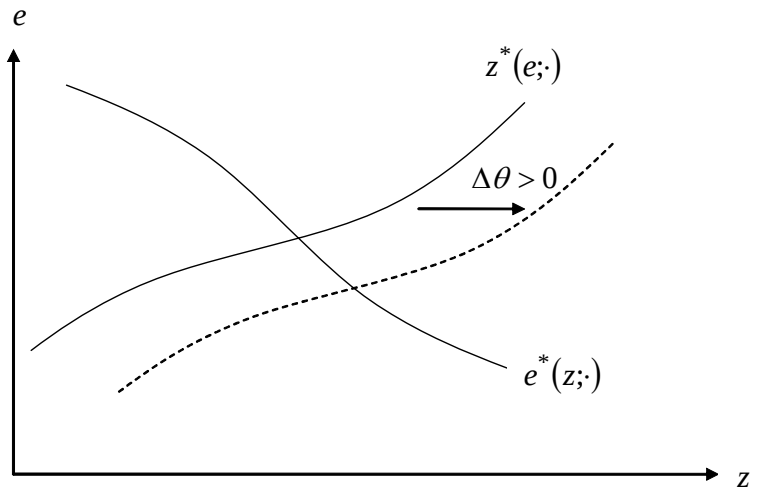

Figure 3: Effects of stronger complementarities.

When θ increases, $e^*(z;.)$ is unaffected (since the entrepreneurial option is unchanged), whereas $z^*(e;.)$ shifts to the right. This is because for any level of effort it will be more beneficial to keep the marginal worker type. Consequently, when θ increases the firm raises its wage offer to keep more worker types. When the wage is raised, the outside option becomes less attractive and worker effort decreases.

We may link θ to firm characteristics such as size.[14] If we assume that large firms have stronger economies of scope than small firms, Proposition 2 suggests that workers in small firms put in higher effort and create more start-up activities than workers in large firms.[15]]

[14] One can also relate θ to industry maturity. Initially, firms are small, wages are low and the start-up activities are plentiful. As the industry matures, concentration increases and there are more complementary assets inside the firm, workers get better wage offers inside the firm but are less motivated, and fewer workers leave to start up their own businesses. This provides a simple argument for why entry rates are lower in mature industries. We are not aware of direct evidence relating to this question but note that Long & Link (1983) find that firms in more concentrated markets have lower turnover.

[15] Economies of scope is the purported motive behind many mergers and acquisitions. Such a motive would generate a positive link between firm size and economies of scope. The extent to which mergers do in fact create economies of scope (rather than say market power) is the topic of a large literature, whose findings are not conclusive. For a recent contribution to this literature, see Gomes & Livdan (2004).

The reason is that larger firms have more complementary assets, and pay higher wages to reduce turnover. Our arguments are therefore consistent with the empirical regularities that larger firms have lower turnover (Oi (1983), Evan & MacPherson (1996)) and pay higher wages (Fox (2004)).[16]

One environment that may be used to evaluate the theory is firms in the aftermath of mergers and acquisitions. Mergers and acquisitions, particularly in the technology sector, are often motivated by gaining economies of scope. Our predictions would be that after such mergers, wages per worker should increase and turnover due to workers pursuing start-up opportunities should drop. Conyon et al. (2004) finds that wages do tend to increase following mergers.[17]

3.4 Property rights protection

In this section we study the effects of changes in property rights protection, interpreted as the probability of the firm winning in court.

Proposition 3 *Stronger intellectual property rights (increased ϕ)*
i) decrease effort AND
ii) has ambiguous effect on wages and turnover.

Proof. See Appendix. ■

The effects from strengthened intellectual property rights are illustrated in Figure 4.

[16] Henderson & Cockburn (1996) find a positive relation between economies of scope and R&D success measured by "significant" patents for a sample of biotech companies. This suggest that the direct positive effect on productivity from an increased θ dominates a possible negative effect on productivity from reduced effort in their context.

[17] Brown & Medoff (1987) reports a similar finding. Interestingly, Conyon et al. (2004) finds that the increased wage effect is larger for mergers by firms that are in the same industry. Such mergers are arguably where one would expect the complementarity gain to be larger.

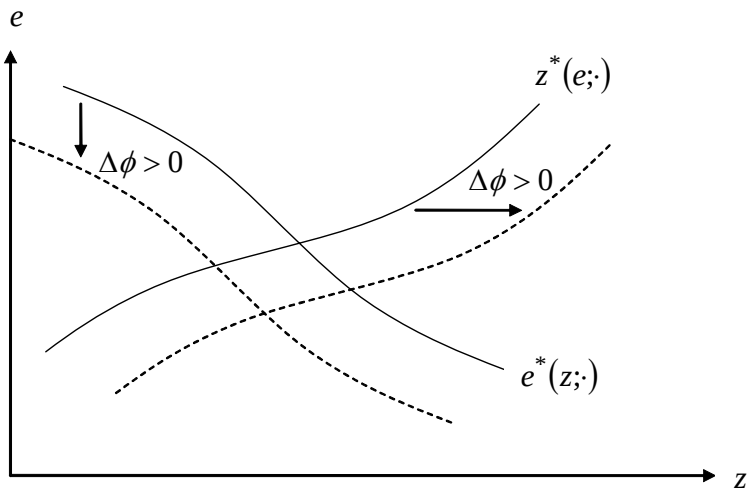

Figure 4: Effects from strengthened intellectual property protection.

When ϕ increases, the worker gets weaker incentives to exert effort because the entrepreneurial payoff is smaller. Hence $e^*(z, .)$ shifts downwards. An increased ϕ makes it cheaper for the firm to keep the marginal worker, because the entrepreneurial option has become less attractive, and $z^*(e; .)$ shifts to the right.[18] Both these two effects pull unambiguously in the direction of a lower worker effort.

The effect on the continuation wage of an increased ϕ depends on forces that counteract each other. An increased ϕ makes it less expensive to keep the marginal worker by an increased continuation wage and, in isolation, induces the firm to increase its wage offer. On the other hand, an increased ϕ reduces effort and makes workers leaving less costly (since the firm more likely wins the litigation case). These two effects lead in isolation to a lower wage offer. The sum of all three effects is ambiguous.

Legal scholars argue that the Massachusetts courts are more "pro-firm" while the Californian courts are "pro-employee" (Hellmann, 2007) when they interpret no-compete clauses and other features of contract law. Proposition 3, part (i), then has resonance in Saxenian (1994), which argues that firms along Route 128 in Massachusetts have fared less well than their counterparts in Silicon Valley.[19]

[18] There is also the counter-acting effect of workers leaving becoming less costly when ϕ increases, since more is retained in court. This effect is dominated in optimum.

[19] Variation in strength of property rights may vary with time or accross industries (OECD, 1998, Cohen et al., 2000). For example, up to the 1980-ies, software innovations were difficult to patent in the

On welfare, we argue based on Proposition 3 that the efficient intellectual property rights should balance the beneficial ex-ante effects from motivating workers against the negative ex-post effects on the use of complementary assets.[20] We note that existing policy literature (see Scotchmer (2004)) typically argues that intellectual property rights should be strong when ex-ante effects (on firms' R&D investments) are important relative to ex-post effects (on the use of innovations). Our analysis complements the existing literature by suggesting that intellectual property rights should be *weak* when the ex-ante effects (on worker initiative) are relatively important and *strong* when the ex-post effects (on the use of complementary assets) are important.

4 Discussion

The purpose of our framework has been to clarify our understanding of the relationship between variables that limit a worker's ability to profit by leaving the firm and the incentive that leaving gives the worker to exert effort. The most important assumption underlying our analysis is that the firm and the worker have limited instruments in alleviating the incentive problems that arise because of asymmetric information at the wage bargaining stage. In this section we discuss several potential mechanisms that could alleviate these problems.

Out-of court settlement. Many intellectual property conflicts are settled before they reach the court. In our context, where the value of the idea is not contractible, it is most natural to think of such pretrial-negotiations as a situation where the firm offers the worker to pay a licensing fee as a compensation for using the idea. Suppose that the firm offers the worker to pay a fixed licensing fee L.[21] If L is accepted by the worker, the

U.S. unless embedded in hardware (like mainframe computers or pizza ovens). Landmark court decisions in the mid 90-ies dramatically improved the scope of patenting software (Cohen & Lemley, 2001). Such variation in property rights protection across industries or time may be explored in light of part (i) of Proposition 3.

[20] Two features of the efficient ϕ can be noted. First, $\phi = 1$ can never be strictly optimal. The intuition is that if $\phi = 1$ and the firm sues, no workers will leave and effort will be zero. When $\phi = 1$ the marginal gain in effort from decreasing ϕ is therefore large while the marginal turnover cost is small. Second, $\phi = 0$ cannot be optimal if θ is close to 1. The intuition is that if $\phi = 0$ and θ is close to 1 the firm's profits must be negative and the worker would not be employed in the first place. Therefore, when θ is close to 1, the optimal ϕ must be interior.

[21] A variable licensing fee depending on sales or profit of the new firm is similar to profit sharing, as

parties save litigation costs and the firm must refrain from suing the worker. If the offer is rejected, the worker and firm meet in court as discussed before. In choosing L, the firm balances the gain from increased licensing fee from accepting worker types and the loss due to lower acceptance rate and consequent litigation costs. Our analysis suggests that the equilibrium outcome splits the value of ideas into three intervals. The first interval consists of workers with the poorest ideas. These workers accept the continuation wage offered and stay inside the firm. The second interval consists of workers with better ideas. These workers leave the firm and are litigated by the firm since they do not accept the suggested licensing agreement (out-of-court settlement). The third interval consists of workers with the best ideas. These workers accept the licensing contract. Lerner (2004) collected data on all litigation cases for a sample of firms from Middlesex, Massachusetts (the borough in which the hi-tech area Route 128 is located). Amongst others, Lerner finds that larger firms are more involved with litigation cases involving intellectual property rights than small firms. Our analysis of pretrial negotiations suggests that the cases that end up in court (and hence observed by empiricists) are intermediate in terms of value, and may therefore be the "tip of the iceberg".

Profit sharing. We have assumed that profit sharing schemes between the firm and the agent are not feasible. There are two versions of profit sharing we can take into account. First, the firm might offer the worker shares in the company if he stays on. This could possibly solve the efficiency loss problems due to turnover since the agent's payoff would depend on the quality of the idea also if he stays on in the firm (a higher stock price of the firm if the idea is valuable). However, even if profit sharing through stocks (or stock options) might give the agent stronger incentives to stay on in the firm, they would typically only marginally do so, since the increased value of the firm due to a good project would have to be shared with all the other shareholders of the company (Kim & Marschke, 2005).[22]

A better solution than awarding the worker stocks might therefore be for the firm to allow the worker to set up his own company and, in exchange for not suing the worker, get

discussed below.

[22] If the firm is small, the worker might get a substantial share of the firm if he stays. This is consistent with anecdotal evidence of key workers in Silicon Valley firms having significant ownership stakes in their companies.

a share of the profits of the new company. Although such worker-initiated spin-offs are quite common (for example spin-offs from the MIT Engineering School) we see limitations to this solution. The first is the obvious one that such a company would not necessarily enjoy the complementary assets that the idea would enjoy if developed by the firm. In that case it might actually be more efficient that the dispute is taken to court, since then the idea would be developed inside the firm with a positive probability. Second, by the unverifiable nature of early-stage innovations, it is not clear what would stop the worker to neglect the spin-off and rather develop the idea inside a different company (Anton & Yao, 1995). In line with this argument Anand & Khanna (2000) find in their sample of UK firms that there are few licensing contracts in markets were it is "difficult to clearly specify the content and boundaries of knowledge and other intangible assets" (p. 126). Arora and Ceccagnoli (2006) reports a similar finding with the use of US data. If it is difficult to use licensing, or profit sharing, we are back in a similar situation to the one we focused on in our model.

Worker signaling. Instead of profit sharing, an alternative way to let the agent's payoff depend upon the quality of the idea would be to let the informed worker demand a continuation wage rather than having the (uninformed) firm offer a wage. This modeling approach, which would rely upon the worker credibly threaten to leave if his demand is not satisfied, opens up for signaling equilibria where a higher worker type would demand a higher wage to stay in the firm.[23] In such equilibria, the firm's decision about whether to accept the offer must be probabilistic and the firm must be indifferent between accepting and rejecting the worker's demand (if the firm did not play a mixed strategy, all workers would independently of the value of their ideas suggest the highest wage that would be accepted and we would have a pooling equilibrium). In the signaling equilibrium, workers with better ideas will get a higher expected wage (which gives an additional reason to exert effort compared to in the main analysis) and the probability of turnover will increase in the quality of the generated idea. The analytical solution to the signaling equilibrium is analytically complex, but our numerical analysis does not suggest that our results would

[23]Separation occurs because a lower type worker would have more to lose from having his demand rejected than a higher type agent, because the value of the outside option is lower for the former. Our analysis of the signaling equilibrium is available upon request. Hvide (2005) performs a related analysis.

differ in a major way from the present analysis.

5 Conclusion

We have developed a theoretical framework to study how complementarities and intellectual property rights affect the management of knowledge workers. We report three sets of findings. First, firms strongly protected by property rights may not sue leaving workers in order to motivate effort, while firms weakly protected by complementary assets must sue in order to obtain positive profits. Second, firms with more complementary assets pay higher wages and have lower turnover, but such higher pay has a detrimental effect on worker initiative. Third, we suggest that the socially optimal intellectual property rights protection strikes the balance between the efficient use of complementary assets and worker initiative.

We see three areas of application for our work. First, our findings on optimal suing policy might be useful to firms deliberating which attitude to take vis-a-vis leaving workers. Our analysis suggests a clear trade-off: more suing gives the firm a larger piece of the cake if a worker leaves, but also gives less worker initiative and hence a smaller cake. Second, our results that stronger complementarities imply higher wages, less turnover, and less worker initiative gives a set of hypotheses to test for in personnel data on R&D intensive firms. These predictions are not obvious; for example the efficiency wage theory of Shapiro & Stiglitz (1986) predicts that higher wages should lead to workers exerting more effort (because of increased cost to the worker of being fired). Third, our results on the effects of property rights legislation may be of interest to policy makers that aim to better understand the effects of changes in intellectual property rights legislation. One case that comes to mind is the current discussion in Europe on the appropriate patent protection for software innovations: we suggest that strengthened protection may reduce turnover costs but may also decrease the productivity of knowledge-work due to less motivated workers.

6 References

Aghion, P. & J. Tirole (1994). The Management of Innovation. *Quarterly Journal of Economics*, 113, 1185-1209.

Anand, N. B. & T. Khanna (2000). The structure of licensing contracts, *Journal of Industrial Economics*, 48, 103-135.

Anton, J & D. Yao (1994). Expropriations and Inventions: Appropriable Rents in the Absence of Property Rights. *American Economic Review*, 84, 190-209.

Anton, J & D. Yao (1995). Start-ups, Spin-offs, and Internal Projects. *Journal of Economics, Law, and Organization*, 11, 362-78.

Anton, J & D. Yao (2002). The Sale of Ideas: Strategic Disclosure, Property Rights and Contracting Abstract. *Review of Economic Studies*, 69, 513-531.

Anton, J & D. Yao (2004). Little Patents and Big Secrets: Managing Intellectual Property. *Rand Journal of Economics*, 35, 1-22.

Arora, A & M. Ceccagnoli (2006). Patent Protection, Complementary Assets, and Firms' Incentives for Technology Licensing. *Management Science*, 52, 293–308.

Bebchuk, L. A. (1984). Litigation and Settlement under Imperfect Information. *RAND Journal of Economics*, 15, 404-415.

Brown, C. C. & J. L. Medoff (1987). The Impact of Firm Acquisitions on Labor. NBER working paper 2273.

Cohen, J. & M. A. Lemley (2001). Patent Scope and Innovation in the Software Industry. *California Law Review*, 89, 1-57.

Cohen, W. M., R. P. Nelson & J. P. Walsh (2000). Protecting their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not). NBER working paper 7552.

Conyon, M. J., S. Girma, S. Thompson & P. W. Wright (2004). Do Wages Rise or Fall Following a Merger? *Oxford Bulletin of Economics and Statistics*, 66, 0305-9049.

Cooper, A. (1985). The Role of Incubator Organizations in the Founding of Growth-oriented Firms. *Journal of Business Venturing*, 1, 75-86.

Drucker, P. (1969). Age of Discontinuity: Guidelines to our Changing Society. *Transaction Publishing.*

Even, W. & D. MacPherson (1996). Employer Size and Labor Turnover: The Role of Pensions. *Industrial & Labor Relations Review*, 49, 707-28.

Fisk, C. L. (2001). Working Knowledge: Trade Secrets, Restrictive Covenants in Employment, and the Rise of Corporate Intellectual Property 1800-1920. *Hastings Law Journal*, 441-528.

Fox, J. (2004). Employer Size Wage Gap Revisited, Mimeo, University of Chicago, Economics Department.

Glynn, J. & P. Mukherjee (2003). Cadence vs. Avant! Case E-61A/B, Stanford Graduate School of Business.

Gomes, J. & D. Livdan (2004). Optimal Diversification: Reconciling Theory and Evidence. *Journal of Finance*, 59, 507-35.

Gompers, P., J. Lerner & D. Scharfstein (2005). Entrepreneurial Spawning: Public Corporations and the Genesis of New Ventures, 1986-1999. *Journal of Finance*, 60, 577-614.

Griliches, Z. (1990), Patent Statistics as Economic Indicators: A Survey. *Journal of Economic Literature*, 28, 1661-1707.

Guedj, I. & D. Scharfstein (2004). Organizational Scope and Investment: Evidence from the Drug Development Strategies of Biopharmaceutical Firms. Mimeo, Harvard Business School.

Hellmann, T. (2003).When Do Employees Become Entrepreneurs? Research paper 1770, Stanford University GSB. Forthcoming, *Management Science*.

Henderson, R. & I. Cockburn (1996). Scale, Scope, and Spillovers: The Determinants of Research Productivity in Drug Discovery. *Rand Journal of Economics*, 27, 32-59.

Hvide, H. K. (2005). Firm Size and the Quality of Entrepreneurs. CEPR working paper 4979. Available at www.ssrn.com.

Kim, J. and G. Marschke (2005). Labor Mobility of Scientists, Technological Diffusion, and the Firm's Patenting Decision. *Rand Journal of Economics*, 36, 298-317.

Lanjouw, J. O. & J. Lerner (1998). The Enforcement of Intellectual Property Rights: A Survey of the Empirical Literature. *Annales d'Economie et Statistique*, 49-50, 223-46.

Lanjouw, J. O. & M. Schankerman (1997). Stylized Facts of Patent Litigation: Scope, Value and Ownership. Unpublished working paper, Yale University.

Lemley, M. A. & C. Shapiro (2004). Probabilistic Patents. *Journal of Economic Perspectives*, 19, 75-98.

Lerner, J. (2004). The Choice of Intellectual Property Protection: Evidence from Civil Litigation. Mimeo, Harvard Business School.

Long, J. E. & A. N. Link (1983). The Impact of Market Structure on Wages, Fringe Benefits, and Turnover. *Industrial & Labor Relations Review*, 36, 239-250.

Lowry, S. (1988). Inevitable Disclosure Trade Secret Disputes: Dissolution of Concurrent Property Interests. *Stanford Law Review*, 519.

Mansfield, E. (1986). Patents and Innovation: An Empirical Study. *Management Science*, 32, 173-81.

Motta, M. & T. Rønde (2003). Trade Secret Laws, Labor Mobility. CEBR discussion paper 2003-17.

Møen, J. (2005). Is Mobility of Technical Personnel a Source of R&D Spillovers? *Journal of Labor Economics*, 23, 81-114.

Neef, D. (1999). Rethinking Economics in the Knowledge-Based Economy. In Neef, D., G. A. Siesfeld & J. Cefola, The Economic Impact of Knowledge, 3, 4. Butterworth Press.

Oi, W. (1983). The Fixed Employment Costs of Specialized Labor, in J. E. Triplett (ed.) The Measurement of Labor Costs, Chicago, University of Chicago Press.

Oyer, S. & S. Schaefer (2005). Why Do Some Firms Give Stock Options To All Employees? An Empirical Examination of Alternative Theories. *Journal of Financial Economics*, 76, 99-133.

Packard, D. (1995). The HP Way: How Bill Hewlett and I Built Our Company. Reed Business Information, Inc.

Pakes, A. & S. Nitzan (1983). Optimum Contracts for Research Personnel, Research Employment, and the Establishment of "Rival" Enterprises. *Journal of Labor Economics*, 1, 345-365.

Priest, G. & B. Klein (1984). The Selection of Disputes for Litigation. *Journal of Legal Studies*, 8, 1-56.

Reinganum, J. F. & L. L. Wilde (1986). Settlement, Litigation, and the Allocation of Litigation Costs. *Rand Journal of Economics*, 17, 577-566.

Roberts, J. (2004). The Modern Firm: Organizational Design for Performance and Growth. *Clarendon Lectures in Management Studies*.

Shapiro, C. & J. E. Stiglitz (1984). Equilibrium Unemployment as a Worker Discipline Device. *American Economic Review*, 74, 433-44.

Saxenian, A. (1994). Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Cambridge: Harvard University Press.

Scotchmer, S. (2004). Innovation and Incentives. MIT Press.

Siegelman, P. & J. Waldfogel (1996). A Taxonomy of Disputes: New Evidence through the Prism of the Priest and Klein Model. Working paper, Yale University.

Stone, K. V. W, (2002). Knowledge at Work: Disputes over the Ownership of Human Capital in the Changing Workplace. *Connecticut Law Review*, 34, 721-63.

Subramanian, N. (2005). The Economics of Intrapreneurial Innovation. *Journal of Economic Behavior and Organization*, 58, 487-510.

Teece, D. J. (1986). Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy. *Research Policy*, 15, 285-305.

Waldfogel, J. (1995). The Selection Hypothesis and the Relationship between Trial and Plaintiff Victory. *Journal of Political Economy*, 103, 229-60.

7 Appendix: Proofs

Proof of Lemma 1 (effort and the suing decision): Let us first examine the no suing case (Case II). Equilibrium is then given by the values of (z, e) which simultaneously solves equations (6) and (8). Consider the "best-response" functions $e^*(z;.)$ and $z^*(e;.)$ that are implicitly defined by (6) and (8). Shorten the notation by writing just g and G instead of $g(z-e)$ and $G(z-e)$. By the implicit function theorem we have that $\frac{\partial e^*}{\partial z} = -\frac{U_{ez}}{U_{ee}}$ and $\frac{\partial z^*}{\partial e} = -\frac{\Pi_{ze}}{\Pi_{zz}}$. Since $U_{ee} < 0$ by the agent's second order condition and, as can easily be shown, $U_{ez} = -\frac{g}{U_{ee}} > 0$, we must have $\frac{\partial e^*}{\partial z} < 0$. Since $\Pi_{zz} < 0$ by the firm's second order condition and $\Pi_{ze} = -\Pi_{zz} + (\theta - 1)g$, we must have that $\Pi_{ze} > 0$ and therefore $\frac{\partial z^*}{\partial e} > 0$. Note that since $\frac{\partial e^*}{\partial z} < 0$ and $\frac{\partial z^*}{\partial e} > 0$ then for any for any (ϕ, θ) there is a

unique equilibrium in (z, e).[24]

To evaluate the effect on equilibrium values of (z, e) from the firm changing its suing policy, we evaluate the effects on $e^*(z;.)$ and $z^*(e;.)$ in turn. From equation (6), the agent's marginal gain from exerting effort under the no suing regime equals $1-G(z-e)$. From equation (3), the agent's marginal gain from exerting effort under the suing regime equals $(1-\phi)(1-G(z-e))$. Since $(1-\phi)<1$, the agent's marginal incentives (for given z) is stronger under no suing, and e^* is higher under no suing than under suing. Hence when the firm changes its suing policy from no suing to suing, the $e^*(z;.)$ function shifts to the south in the (z, e) space in Figure 2.

Now consider the effect on $z^*(e;.)$ from changing the firm's suing policy. Denote Π_z under no suing, given by equation (8), by Π_z^n, and denote Π_z under suing, given by equation (5), by Π_z^s. Combining (5) and (8) then gives,

$$\Pi_z^s = (1-\phi)\Pi_z^n + vg. \tag{9}$$

Now denote the optimal z under no suing for z_n^* and the optimal z under suing for z_s^*. By definition, $\Pi_z^n(z_n^*) = 0$. Since $(1-\phi)<1$ and $vg>0$ it follows from the global concavity of Π_z^n that $z_s^* > z_n^*$. Hence when the firm changes its suing policy from no suing to suing, $z^*(e;.)$ shifts to the east in Figure 2.

To summarize, we have shown that moving from the no suing to the suing regime has two effects. First, $e^*(z;.)$ shifts to the south in Figure 2, while $z^*(e;.)$ shifts to the east. The equilibrium level of effort must decrease when the firm moves from a no suing to a suing regime.

Proof of Proposition 1: (i)We show that if the firm does not sue and $\theta = 1$, the firm's profits are negative. First note that if the firm does not sue, then $z = B$. For $\theta = 1$, the profits therefore equal $\int_{-\infty}^{B-e}(x-B)g(\epsilon)d\epsilon$, where $x = e+\epsilon$. This expression is negative because $x < B$ for any $\epsilon \in (-\infty, B-e]$. By continuity, the firm's profits are also negative for θ close to 1. (ii) We now construct an example where suing leads to non-positive profit while not suing leads to positive profit. Let $g(\epsilon)$ be uniformly distributed on $[-\frac{1}{2}, \frac{1}{2}]$ and

[24] This statement has the qualification that e(;.) or e(z;.) could be discontinuous for isolated values of (ϕ,θ), in which case there could be multiple equilibria for such values.

$c(e) = \frac{\gamma}{2}e^2$. For a given B the worker chooses e to maximize

$$\begin{aligned} U &= \int_{-\frac{1}{2}}^{\frac{B}{1-\phi}-e} Bg(\epsilon)d\epsilon + \int_{\frac{B}{1-\phi}-e}^{\frac{1}{2}} (1-\phi)(\epsilon+e)\, g(\epsilon)d\epsilon - c(e) \\ &= \frac{1}{2}B + \frac{1}{1-\phi}\left(B^2 + Be\phi - Be\right) \\ &\quad -\frac{1}{8(1-\phi)}(2B+2e-\phi-2e\phi+1)(2B-2e+\phi+2e\phi-1) - \frac{\gamma}{2}e^2. \end{aligned} \tag{10}$$

By differentiating with respect to e and solving, we have the unique interior solution $e^* = \frac{1}{1-\gamma-\phi}\left(B + \frac{1}{2}\phi - \frac{1}{2}\right)$, with second order condition $1-\phi-\gamma < 0$. For a given e the firm chooses B to maximize

$$\begin{aligned} \Pi &= \int_{-\frac{1}{2}}^{\frac{B}{1-\phi}-e} (\theta(e+\epsilon) - B)g(\epsilon)d\epsilon + \int_{\frac{B}{1-\phi}-e}^{\frac{1}{2}} (\phi\theta(e+\epsilon) - v)g(\epsilon)d\epsilon \qquad (11) \\ &= \frac{1}{8(1-\phi)}\left(\begin{array}{c} (e)^2\left(8\theta\phi - 4\theta - 4\theta\phi^2\right) + e\left(8B - 8v + 4\theta - 8B\phi + 8v\phi - 4\theta\phi^2\right) \\ +8Bv - 4v - 4B - \theta + 4B\phi + 4v\phi + 2\theta\phi - 8B^2 + 4B^2\theta - \theta\phi^2 \end{array}\right) \end{aligned}$$

By differentiating with respect to B and solving the first order condition, we have the unique interior solution

$$B^* = \frac{2v + \phi + 2e - 2e\phi - 1}{4 - 2\theta} \tag{12}$$

The second order condition is $\theta < 2$. By using $e^* = \frac{1}{1-\gamma-\phi}\left(B + \frac{1}{2}\phi - \frac{1}{2}\right)$ we have

$$B^* = \frac{2v\gamma - \gamma - 4\phi - 2v + 2v\phi + \gamma\phi + 2\phi^2 + 2}{2(2\gamma + \phi + \theta - \theta\gamma - \theta\phi - 1)} \tag{13}$$

By setting $\phi = 0$ and $v = 0$ the above calculations give us the profit in the no suing case,

$$\Pi = \frac{1}{8}\frac{(\gamma-2)^2(\theta-1)^2(2-\theta)}{(\theta\gamma - 2\gamma - \theta + 1)^2} \tag{14}$$

which always is positive given that the second order condition holds.

On the other hand if the firm sues and the firm has strong IP, $\phi = 1$, the worker has no incentives to work, $e^* = 0$, and since the entrepreneurial is option is worthless to the

worker the firm can keep all workers by setting $B^* = 0$. In the absence of worker effort, the expected idea is worth 0 for the firm $\int_{-\infty}^{\infty} \epsilon g(\epsilon) d\epsilon = 0$. Since $\Pi = 0$ in case of suing the firm chooses in this case a no-suing policy.

Proof of Proposition 2 and Proposition 3: We are interested in the effect of a change in θ or ϕ on the equilibrium e, z, T in the case where the firm sues (Case I) and in the case where the firm does not sue (Case II). We label the turnover rate as T, where $T = 1 - G(z - e)$. Let us consider Case I, when the firm sues. On reduced form, we can suppress B and write the two first order conditions (3) and (5) as,

$$\begin{aligned} \Pi_z(z, e, \phi, \theta) &= 0 \\ U_e(e, z, \phi) &= 0. \end{aligned} \tag{15}$$

Denote partials by subscript and totally differentiate (15),

$$\begin{aligned} \Pi_{zz} dz + \Pi_{ze} de + \Pi_{z\phi} d\phi + \Pi_{z\theta} d\theta &= 0 \\ U_{ee} de + U_{ez} dz + U_{e\phi} d\phi &= 0. \end{aligned} \tag{16}$$

We want to examine the effect of changing θ and ϕ, respectively. Solving the system yields.

$$\begin{aligned} \frac{dz}{d\phi} &= \frac{\Pi_{z\phi} U_{ee} - \Pi_{ze} U_{e\phi}}{\Pi_{ze} U_{ez} - \Pi_{zz} U_{ee}}, \frac{de}{d\phi} = \frac{\Pi_{zz} U_{e\phi} - U_{ez} \Pi_{z\phi}}{\Pi_{ze} U_{ez} - \Pi_{zz} U_{ee}} \\ \frac{dz}{d\theta} &= \frac{\Pi_{z\theta} U_{ee}}{\Pi_{ze} U_{ez} - \Pi_{zz} U_{ee}}, \frac{de}{d\theta} = \frac{-U_{ez} \Pi_{z\theta}}{\Pi_{ze} U_{ez} - \Pi_{zz} U_{ee}}. \end{aligned} \tag{17}$$

Let us now evaluate the partials. Differentiating U_e from equation (3),

$$\begin{aligned} U_{e\phi} &= -(1 - G(z - e)) < 0 \\ U_{ee} &= (1 - \phi) g(z - e) - c''(e) < 0 \\ U_{ez} &= -(1 - \phi) g(z - e) < 0. \end{aligned} \tag{18}$$

Note that $U_{ee} = -U_{ez} - c''$. Now the firm. Differentiating Π_z from equation (5),

$$\begin{aligned}
\Pi_{z\phi} &= -z(\theta-1)g + G(z-e) > 0 \qquad (19)\\
\Pi_{zz} &= (\theta-1)(1-\phi)g(z-e) + (v + z(\theta-1)(1-\phi))g'(z-e) - (1-\phi)g(z-e) < 0\\
\Pi_{ze} &= -\Pi_{zz} + (\theta-1)(1-\phi)g(z-e) > 0\\
\Pi_{z\theta} &= (1-\phi)zg(z-e) < 0.
\end{aligned}$$

Now return to (17). The denominator equals $\Pi_{ze}U_{ez} - \Pi_{zz}U_{ee}$. This expression is negative given the signs of the partials in (18) and (19). Both terms in the numerator of $\frac{de}{d\phi}$ are positive and hence $\frac{de}{d\phi} < 0$. Both terms in the numerator of $\frac{de}{d\theta}$ are negative and hence $\frac{de}{d\theta} > 0$. Neither $\frac{dz}{d\phi}$ nor $\frac{dz}{d\theta}$ can be signed unambiguously since the terms in the numerator are of different sign. Now consider turnover. Recall that $T = (1 - G(z-e))$. Therefore

$$\frac{dT}{di} = g(z-e)(\frac{de}{di} - \frac{dz}{di}), \text{ where } i = \theta, \phi. \qquad (20)$$

Denote the denominator of (17) by $D < 0$. Substitute (17) into (20) using $U_{ee} = -U_{ez} - c''$,

$$\begin{aligned}
\frac{dT}{d\theta} &= (-U_{ez}\Pi_{z\theta} - \Pi_{z\theta}U_{ee})/D \qquad (21)\\
&= -\Pi_{z\theta}(U_{ee} + U_{ez})/D = c''\Pi_{z\theta}/D < 0\\
\frac{dT}{d\phi} &= (\Pi_{zz}U_{e\phi} - U_{ez}\Pi_{z\phi} - \Pi_{z\phi}U_{ee} + \Pi_{ze}U_{e\phi})/D\\
&= [\Pi_{zz}U_{e\phi} - (-U_{ee} - c'')\Pi_{z\phi} - \Pi_{z\phi}U_{ee} + (-\Pi_{zz} + k)U_{e\phi}]/D\\
&= (kU_{e\phi} + c''\Pi_{z\phi})/D,
\end{aligned}$$

where $k = (\theta-1)(1-\phi)g(z-e)$. Hence we have established that $\frac{dT}{d\theta} < 0$.

To show that the effect on wages and turnover from stronger intellectual property rights is ambiguous consider the example introduced in Proposition 1. Since the density function is uniform on $[-\frac{1}{2}, \frac{1}{2}]$, turnover is given by $T = 1 - G(z-e) = 1 - (z-e) = 1 - \left(\frac{B}{1-\phi} - \frac{1}{1-\gamma-\phi}\left(B + \frac{1}{2}\phi - \frac{1}{2}\right)\right)$. Observe that $\frac{dT}{d\phi} = -\left(\frac{1}{1-\phi} - \frac{1}{1-\phi-\gamma}\right)\frac{dB}{d\phi} + \frac{\partial T}{\partial \phi}$. Let $v = 0.05$, $\gamma = 1$, and $\theta = 1.8$. which implies that $B^* = \frac{1}{4}\frac{1}{5-4\phi}\left(20\phi^2 - 29\phi + 10\right)$ and

$\frac{dB^*}{d\phi} = -\frac{5\,(4\phi-7)\,(4\phi-3)}{4\,(4\phi-5)^2}$. Note that if $\phi = 0.3$, then $\frac{dB^*}{d\phi} < 0$ and $\frac{dT}{d\phi} > 0$. However, if $\phi = 0.9$, then $\frac{dB^*}{d\phi} > 0$ and $\frac{dT}{d\phi} < 0$. Hence, the signs of the effects on wage and turnover are different in the two cases.

Let us now consider case II, when the firm does not sue. In that case the partials are

$$\begin{aligned} U_{e\phi} &= 0 \\ U_{ee} &= \theta g(z-e) - c''(e) < 0 \\ U_{ez} &= -\theta g(z-e) < 0 \end{aligned} \tag{22}$$

$$\Pi = \int_{-\infty}^{z-e} (\theta(e+\epsilon) - B) g(\epsilon) d\epsilon - F. \tag{23}$$

The marginal profits are

$$\Pi_z = z\theta g(z-e) - G(z-e), \tag{24}$$

and the partials are,

$$\begin{aligned} \Pi_{z\phi} &= 0 \\ \Pi_{zz} &= \theta g(z-e) + z\theta g'(z-e) - g(z-e) < 0 \text{ Firm's SOC} \\ \Pi_{ze} &= -\Pi'_z + \theta g(z-e) > 0 \\ \Pi_{z\theta} &= z g(z-e) > 0, \end{aligned} \tag{25}$$

which gives,

$$\begin{aligned} \frac{dz}{d\phi} &= 0,\ \frac{de}{d\phi} = 0 \\ \frac{dz}{d\theta} &= \frac{\Pi_{z\theta} U_{ee}}{\Pi_{ze} U_{ez} - \Pi_{zz} U_{ee}} \gtrless 0,\ \frac{de}{d\theta} = \frac{-U_{ez}\Pi_{z\theta}}{\Pi_{ze} U_{ez} - \Pi_{zz} U_{ee}} < 0, \end{aligned} \tag{26}$$

A changed ϕ has no effect on turnover. The effect on turnover of increased θ is negative as when the firm sues.