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TRADE SECRET LAWS, LABOUR MOBILITY AND INNOVATIONS

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ABSTRACT

Trade Secret Laws, Labour Mobility and Innovations*

We show that when the researcher's (observable but not contractible) contribution to innovation is crucial, a covenant not to compete (CNC) reduces effort and profits under both spot and relational contracts. Having no CNC allows the researcher to leave for a rival. This alleviates a commitment problem by forcing the firm to reward a successful researcher. If the firm's R&D investment mainly matters, however, including a CNC in the contract is optimal, as it ensures the firm's incentives to invest.

JEL Classification: J30, K20, L14, O31 and O34
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1 Introduction

The effects of knowledge spillovers from workers' mobility have recently attracted a lot of attention in various disciplines, coinciding with the suggestion that one of the key ingredients of Silicon Valley's success is the high labor turnover of engineers and software programmers (Saxenian, 1994).[1] According to this argument, knowledge spillovers among firms located in the same district stimulate innovation and economic growth.

The objective of this paper is to investigate the effect upon innovations of trade secret laws and contractual clauses that limit workers' mobility, an issue that has already attracted the attention of legal scholars (Gilson, 1999; Hyde, 2001).

There are different ways in which the law might protect firms' knowledge from misappropriation by former employees. (We refer here to knowledge that cannot be protected by patents and copyright laws.) First, trade secret laws theoretically protect firms' valuable information when an employee leaves. However, these laws are not easily enforceable, apart from cases where the trade secret can be easily identified (a formula, or customer lists) and misappropriation easily observed (theft, espionage, or an employee walking away with documents). Most of the trade secrets of a firm consist of tacit knowledge, and it is very difficult to draw the line between the general knowledge that an employee has received through his education, background, and work experience, and the specific knowledge that he has received from an employer and that one could classify as a trade secret.[2] Accordingly, firms find it hard to prove that there is misappropriation of trade secrets when employees move to other firms.

To overcome the difficulties of trade secret laws, firms might adopt post-employment covenants not to compete (CNCs). These covenants establish that an employee cannot - after termination of his contract with a given employer - work for a competing firm for a given period of time (usually, one or two years) and in a given geographical area.[3] Therefore, they protect trade secrets by eliminating the very mechanism by which they are lost, namely workers' mobility.[4]

To us, the interesting question is why (actual or potential) labor turnover, or the *absence* of contractual clauses that prevent it, should foster innovation. In fact, if firms knew that an employee might leave the company at any time bringing with him the firm's knowledge, they would hardly have an incentive to innovate. The main objective of this paper is

[1] According to Saxenian (1994, p.34), labor turnover in Silicon Valley's electronic industry reached 35 percent a year on average during the Seventies.

[2] Innovations created by an employee in his working hours also belong to the employer according to trade secret laws.

[3] Such covenants are legally enforceable in most European countries and in many US states, as long as they are limited in time and place, they do not unreasonably restrict the right of the employee to find a new job, and protect a legitimate interest of the employer (see among others Hyde, 2001, and Thiébart, 2001). In a few US states, notably California, CNCs are banned.

[4] A very strict enforcement of trade secret laws might achieve the same objective as CNCs. Some recent US decisions have adopted the presumption that former employees would *inevitably* disclose some trade secrets. This would imply that it is not necessary to establish the existence of a trade secret, and *de facto* prohibit employees from moving to competitors. See Gilson (1999), and Hyde (2001, part III, page 5) for a critique of this doctrine.

therefore to analyze the ex-ante effects of CNCs in an environment of weak trade secret laws. Our main result is that when an employee's effort is crucial for R&D, it is optimal not to include a CNC in the employment contract. This alleviates a commitment problem on the side of the firm by forcing it to reward the employee if he makes an innovation (else, he would leave for another firm). Hence, the employee exerts more effort, which leads to more innovation.[5]

Our formalization follows Baker et al. (2002) in assuming that R&D outcomes are observable but not verifiable. It is notoriously hard to measure objectively the output of research. Typically, profits from an innovation accrue long after the research is completed, and they will depend on the effort and talent of the whole organization, from production to aftersales service. Even if it is hard to measure R&D output objectively, it is often possible to measure it subjectively. Therefore, there are typically compensation schemes that do not rely, at least uniquely, on objective measures of R&D success such as patents, publications, and profits.[6]

Within this setting, we consider two types of contracts: fixed wage contracts, and contracts that include a bonus for a successful R&D outcome. First, we show that under fixed wage contracts, an employee exerts no effort if there is a CNC in place, as there is no reward for innovating. On the other hand, if there is no CNC, competing firms will try to 'poach' a successful employee to acquire the innovation. This raises the wage of the employee, and provides him with incentives to exert effort. As a result, there is more innovation without CNCs.

Contrary to what one might expect, repeated interaction between the firm and the employee does not change this result. A CNC also leads to a lower effort even when the contract includes a performance bonus (a so-called 'relational contract'). A relational contract can be sustained only if the employer's future gain from honoring the contract is higher than the profit it makes by deviating from it. When there is no CNC included in the contract, the employee can leave the firm if he is not paid the promised bonus. This threat decreases the firm's payoff from deviating and helps to enforce a relational contract with a higher bonus, resulting in higher effort by the employee and higher profits for the firm.[7]

Innovations are often the combined product of employees' effort and creativity and of the firm's investment. We show that CNCs unambiguously reduce profits and innovation if the employee's effort is crucial. On the other hand, if the firm's investment is more important than the employee's effort, then CNCs find the rationale for their existence:

[5]Note that we consider only the ex-ante effects of labor contracts on innovation. For the argument that knowledge spillovers are beneficial if they are large enough to outweigh the detrimental effects on the incentives to innovate, see Gilson (1999).

[6]The compensation to scientists may take many forms, reflecting the fact that scientific personnel are often as much driven by professional curiosity and recognition as by monetary incentives. Examples are: promotions, additional R&D funds, freedom to pursue pet projects, luncheons and other recognition events. See also Chester (1995) on these issues. For an empirical analysis of compensation schemes in pharmaceutical research, see Cockburn et al. (1999).

[7]Note that whether the worker actually moves to another firm or not in equilibrium is irrelevant for our argument. What matters is that the worker receives an outside offer.

since they prevent a worker from walking away and bringing knowledge to rivals, such covenants maintain the appropriability of the firm's investment and favor innovations.

Our paper is related to several strands of literature. First, it belongs to the literature on implicit contracts initiated by McLeod (1988) and McLeod and Malcomson (1989). Our debt to Baker et al. (1994, 2002) is especially obvious, and indeed we have tried to keep our model as close as possible to their formalization and notation to help readers. Our contribution, relative to theirs, is that we explicitly analyze the role of trade secret laws and CNCs and formalize the process by which a worker can move to a competing firm. The different extensions analyzed (most importantly, the case of two-sided investment) were also not considered by Baker et al. (1994, 2002).

Our paper is also closely related to Aghion and Tirole (1994) and the literature on the efficient allocation of property rights (e.g., Grossman and Hart, 1986). Aghion and Tirole (1994) analyze a contractual relationship between a "customer" and a "research unit", both investing in research. They show that giving the property rights of the innovation to the research unit ("non integrated case") rather than to the customer ("integrated case") is optimal if the research unit's effort is relatively more important than the customer's investment in research. Our result showing that a CNC should be included in the contract only if the firm's investment matters more that the employee's effort is clearly of a similar nature.[8] However, Aghion and Tirole did not model workers' mobility, nor did they study relational contracts.

This paper also belongs to the law and economics literature on trade secrets and CNCs. Apart from the above mentioned works by Gilson (1999) and Hyde (2000), it is worth mentioning Rubin and Shedd (1981) and more recently Posner and Triantis (2001). These papers study the efficiency properties of CNCs in a situation where the firm invests in the training of its employees and compare CNCs with such alternative remedies as specific performance and liquidated damages. They therefore focus on complementary issues to the ones that are at the centre of our paper.

We formalize explicitly the process by which the current employer and a rival firm compete to keep, or hire, a worker who possesses trade secrets. As such, we follow Pakes and Nitzan (1983) and other recent papers that explicitly model knowledge spillovers through labor mobility.[9] However, these papers focus on somewhat different issues than the ones analyzed here.

The basic mechanism we emphasize in this paper is similar to the one identified by the literature on *second-sourcing*. In Farrell and Gallini (1988), licensing a product amounts for a monopolist to committing to future competition (otherwise consumers would fear a lock-in and refrain from buying).[10]

[8]See also Hyde (2000) for a critical discussion of the possible application of Aghion and Tirole's model to the analysis of CNCs, especially as regards shared ownership rights. Merges (2001) also uses the Grossman and Hart's theory to discuss who should own property rights of innovations.

[9]See, for example, Fosfuri et al. (2001) and Rønde (2001).

[10]See also Padilla and Pagano (1997), where committing to share information among lenders increases competition and reduces incentives to engage in opportunistic behaviour.

Burguet et al. (2002) study optimal quitting fees in labor contracts. The productivity of an employee depends on his ability and the quality of the match. The ability of a worker is unknown ex-ante, and the parties set the fees as to minimize the rents appropriated ex-post by outsiders. Quitting fees do not affect the effort exerted and play thus a quite different role from the one of CNCs in our model.

Aghion and Tirole (1997) also explore the idea that giving freedom to an employee may provide incentives to exert effort. The instrument considered is different from ours, as the principal decides whether to give the agent the formal authority to choose his preferred project. A related idea is developed in Puga and Trefler (2002) that study innovation in a system of complements.

Finally, our paper is related to a stream of papers on innovation and start-ups. Lewis and Yao (2001) study worker and knowledge flows in industrial clusters. They show that when the labor market is tight, and employees have more bargaining power, firms choose an open and efficient research environment and more start-ups take place. Cassiman and Ueda (2002) consider a setup where firms have a limited capacity for R&D projects. Established firms thus reject profitable projects, which may lead to start-ups by employees. Both papers study how the legal environment affects the amount of start-ups happening in equilibrium, but they do not look at employees' ex-ante incentives, which is our main focus.

The rest of the paper is organized in the following way. Section 2 presents and solves the base model where only the worker contributes to the innovation. Section 3 looks at the general case where both the firm and the employee invest in R&D. In section 4, we return to the base model and check the robustness of our results by relaxing some of the assumptions. Reassuringly, under these alternative assumptions the qualitative results obtained only change marginally. Section 5 concludes the paper.

2 The model

To understand the role of covenants not to compete we consider a setup where (general) trade secret protection is so weak that it provides no protection of the firm's intellectual property if a key employee leaves for another firm. Including a CNC in the employment contract is thus the only way to protect the intellectual property against 'poaching'. In the next subsection, we describe the game.

2.1 The game

(1) The contract offered At the beginning of the game, Firm 1 offers a contract (s, i, b) to a risk-neutral employee. (The later analysis is mainly concerned with Firm 1, so we will refer to it as 'the firm' when this is unambiguous.) There is a pool of ex-ante identical candidate employees, so we assume that the firm has all the bargaining power at this stage.

The contract can have both a contractible (explicit) and non-contractible (implicit) part. s is the fixed wage, which is contractible. In the base model, we assume that the employee is not credit constrained, so the fixed wage can be negative. In section 4.2, we look at contracting with a wealth and credit constrained employee. $i = CNC$ indicates that a CNC is included in the contract whereas $i = \emptyset$ indicates that there is no such clause. This is, of course, also an explicit part of the contract. If a CNC is included, the employee cannot work for a competitor within the present period, unless a compensation is paid to Firm 1.[11]

The actions of the employee are not observable, but the resulting outcome is observable, although not contractible (that is, not verifiable in court). $b > 0$ is a bonus that the firm promises to pay if the employee's actions lead to a successful outcome. However, since the outcome is not verifiable, the firm is not legally obliged to pay the bonus. The promise of a bonus is thus only kept if the contract is self-enforcing, as we see below.

Notice that we do not consider incentive schemes where the reward depends on the profits realized by the firm, like, e.g., an equity stake. This is mainly a simplifying assumption and it is supposed to capture the idea that the employee has little influence on the overall profits of the firm.[12]

In each period, there is a R&D stage and, if there is an innovation, a marketing stage. The following figure illustrates the timing in each period. The individual steps are explained in detail below.

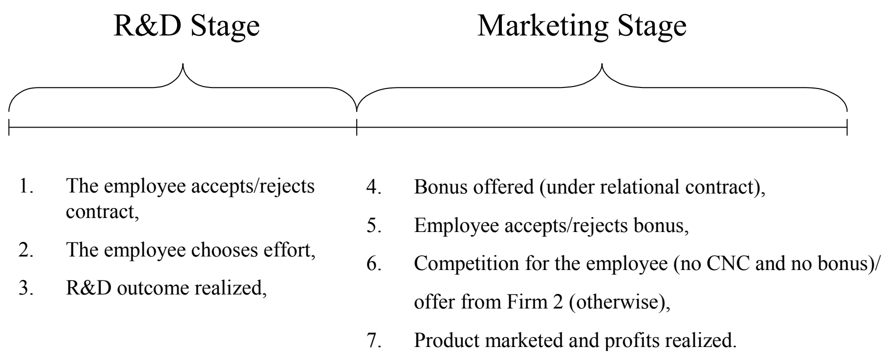

Figure 1. The timing within a period.

(2) The research stage First, the employee decides whether to accept the contract or not.[13] If he rejects the offer, then he works elsewhere in the economy and receives a salary of w_a (the reservation wage). For simplicity, we assume $w_a = 0$.[14] If the employee accepts

[11] After the first market realisation, the current innovation loses value. Therefore, we can restrict our attention to one-period covenants.

[12] In other words, we do not consider the component β of the compensation scheme analysed by Baker et al. (1994, 2002).

[13] Here, there is a difference between the first and later periods. In the first period, the employee accepts or rejects the contract. In later periods, he decides whether to continue working for the firm given the conditions of the contract. In most of the paper, however, the employee earns zero every period, so this difference between the first and the later periods is inessential.

[14] Baker et al. (1994) show that the value of the reservation wage affects the sustainability of the relational contracts. In a previous draft of the paper we have analysed the case where $w_a \geq 0$, and found that it does not affect the comparison between CNCs and no-CNCs. Since assuming zero reservation wage makes the analysis considerably neater, we adopt this assumption.

the offer, he takes an action a, which is the probability that the action leads to a successful outcome, namely an innovation. With a probability $1 - a$, the action leads to an outcome of value 0 for the firm (no innovation). This action has a cost γa^2 for the employee. We will refer to a as the employee's 'effort'.[15]

Finally, at the end of the research stage, the outcome of the employee's effort is observed by all relevant agents in the economy (section 4.5 briefly discusses the case of asymmetric information). We assume that an innovation has only commercial value for one period. Afterwards, it either becomes obsolete or is imitated by competitors. Suppose first that the employee is unsuccessful. Then, no bonus is offered and the employee continues in the firm (whether he stays or leaves is immaterial). The game continues to the next period. On the other hand, if the employee is successful, there is a marketing stage.

(3) The marketing stage If there is a CNC, the timing is the following. Firm 1 decides whether to offer a bonus. If a bonus is offered, the employee accepts it, as he has no other possibility of capitalizing on the innovation. Afterwards, although the CNC prevents the employee from leaving, Firm 1 might decide to let him go if it receives a suitable compensation in exchange. Therefore, Firm 2 decides whether it wants to make an offer to Firm 1 to hire the employee. This offer is either accepted or rejected.

If there is no CNC, the timing is similar. First, Firm 1 decides whether to offer the bonus, b. Next, the employee decides on whether to accept or reject the bonus. If the employee accepts the bonus, he has to stay until after market realization. If the employee rejects the bonus, or no bonus is offered, the firms compete for the employee's services. We model the hiring process, which is discussed in detail in point 5 below, as a first price auction.

The profits depend on whether the employee stays with Firm 1. If the employee stays, Firm 1 can market the innovation as a monopolist. The gross monopoly profits (i.e. gross of wages) are normalized to 1. If the employee leaves, we assume that both firms can market the innovation. The underlying assumption is that the innovation remains within Firm 1, so it needs only to hire a 'production' employee (at the reservation wage) to produce (see footnote 32 for a discussion of the case where the innovation is the employee's private information). In case the employee leaves, Firm 1 and 2 thus both earn gross duopoly profits of ϕ, $\phi \leq 1$.

(4) Infinite repetition of the game The game continues like in 2-3 every period for an infinite number of periods.[16] There is no discounting within a period, but a discount rate of r between periods.

[15] Of course, one should interpret a as the effort made by the employee above a minimal effort which can be specified contractually (number of hours worked, verifiable tasks to be performed, and so on). Therefore, when we talk of 'zero effort' which leads to 'zero profits', these terms need not be taken literally.

[16] We assume that innovations are non-cumulative: the probability of getting an innovation in the following period(s) is the same no matter what has happened in the present period. This, admittedly strong, assumption simplifies the analysis greatly, and relaxing it is unlikely to change the analysis of CNCs qualitatively.

(5) The competition for the employee The competition for the employee, if there is no CNC and the bonus is rejected, is modeled as a first price auction (section 4.3 discusses alternative bargaining assumptions). We will here describe the auction and derive the static Nash equilibrium for future reference. The first step is to find the value of the employee for the firms. There is a pool of identical employees that the firms can hire from. The value of the employee stems only from the innovation that he has made.

If Firm 1 loses the employee it gets ϕ whereas it gets 1 if it keeps him. Hence, its willingness to pay is $1-\phi$. Firm 2 gets ϕ if it hires the employee and 0 otherwise. Hence, its willingness to pay is ϕ. As tie-breaking rule, we assume throughout the paper that the firm with the highest valuation hires the employee. This ensures an equilibrium in pure strategies. Furthermore, we do not consider equilibria in weakly dominated strategies. This implies that the firm with the higher willingness to pay will get the employee by paying a wage equal to the valuation of the other. Therefore, Firm 1 will keep the employee (no job turnover arises) if $1-\phi \geq \phi$, or $\phi \leq 1/2$. In this section, we restrict our attention to $\phi \leq 1/2$, but $\phi > 1/2$ is analyzed in section 4.1. We will say that the 'efficiency effect' holds if $\phi \leq 1/2$.[17]

Suppose first that no CNC is in place and the bonus (if offered) has been rejected. Since $\phi \leq 1/2$, the employee stays with Firm 1 and receives a wage equal to ϕ. Suppose instead that there is a CNC. Here, the employee also stays, as Firm 2 cannot profitably pay Firm 1 enough to compensate for the loss incurred if the employee leaves.

2.2 Spot and relational contracts

We are now ready to analyze the complete model. We consider two types of contracts. First, we look at employment contracts containing only explicit elements, i.e., the fixed wage, s, and possibly a CNC. Following Baker et al. (2002), we denote these 'spot contracts'. Afterwards, we consider contracts where an implicit bonus, b, is added to the contract. These are called 'relational contracts' as they only can be sustained in a long-term relation. Therefore, a contract $(s, i, 0)$ is 'Spot' and a contract $(s, i, b > 0)$ is 'Relational'.

We denote $V_{i,j}$ as the per period profits, where $i \in \{CNC, \emptyset\}$ and $j \in \{S(pot), R(elational)\}$. $V^*_{i,j}$ denotes the equilibrium profits. Finally, $U(a)$ is the utility of the employee in the relevant period as a function of a (the probability that an action results in an innovation).

Before turning to the different contracts, we first analyze a benchmark case where it is possible to contract upon the outcome of the employee's effort.

2.2.1 Benchmark: first best

As a benchmark, it is useful to find the optimal contract when the outcome of the R&D is contractible. The firm can thus commit to paying a bonus if an innovation is made.

[17] In the industrial organization literature, the term "efficiency effect" has been used to describe a situation where the monopoly profit is higher than the sum of the duopoly profits. See for instance Tirole (1988, page 348-50).

Suppose the employee is offered the contract (b, s, CNC). Assuming that the employee accepts the contract, he chooses the a that maximizes his utility $U(a) = ab - \gamma a^2 + s$, which gives the solution $a = b/(2\gamma)$.

The problem of the firm is to maximize its profits subject to the participation and incentive constraint of the employee:

$$\max_{b,s}\{(1-b)a - s\} \quad \text{subject to:} \quad ab + s - \gamma a^2 \geq 0 \text{ and } a = b/(2\gamma).$$

which can be rewritten, after noting that the participation constraint is binding, as: $\max_b\{b(1-b/2)/(2\gamma)\}$. The solution is $b^{fb} = 1$, $s^{fb} = -1/(4\gamma)$, and $a^{fb} = 1/(2\gamma)$; the firm's profit is $V^{fb} = 1/(4\gamma)$. It can easily be verified that this is also the outcome if it is possible to contract directly on a. The bonus b^{fb} is greater than the outside offer ϕ, so the employee always accepts the bonus and stays with the firm. Therefore, it is irrelevant whether a CNC is included in the contract.

In order to avoid corner-solutions, we assume that $\gamma > 1/2$. This ensures that a is smaller than 1 in equilibrium.

2.2.2 Spot contracts

We now turn to the case where it is not possible to contract upon the outcome of the innovation. We first look at spot contracts $(s, i, 0)$.

A covenant not to compete Suppose first that there is a CNC. Since the employee cannot leave, he cannot rely on outside offers to increase his wage after an innovation. His problem is: $\max_a U(a) = (s - \gamma a^2)$, leading to the optimal effort $a = 0$. The firm anticipates that the employee makes zero effort and pays him no more than $s = 0$. Firm 1's expected payoff in this case is

$$V^*_{CNC,S} = 0. \tag{1}$$

No covenant Suppose now that no CNC is included in the employment contract. From the analysis of the hiring process in the previous subsection, we know that *if* the effort leads to an innovation, the firm will pay ϕ to the employee to make him stay. The employee's expected payoff at the moment of deciding his effort is therefore $U(a) = (s + a\phi - \gamma a^2)$, leading to optimal effort $a = \phi/(2\gamma)$.

The problem of Firm 1 is to find the optimal fixed salary given the anticipation that the employee earns ϕ from an innovation. Hence, it solves:

$$\max_s V_{\emptyset,S}(s) = a(1-\phi) - s \quad \text{subject to:} \quad s + a\phi - \gamma a^2 \geq 0 \text{ and } a = \phi/(2\gamma),$$

where the first constraint ensures the participation of the employee. Clearly, this problem is solved by paying him a salary that will give him the reservation wage, that is: $s = -a\phi + \gamma a^2 = -\phi^2/(4\gamma)$. The expected profits of Firm 1 are:

$$V^*_{\emptyset,S} = \frac{\phi(2-\phi)}{4\gamma}. \tag{2}$$

Note that the fixed wage is lower than the reservation wage (i.e., negative). Firm 1 is able to appropriate all monetary rents as the employee is risk-neutral and is not credit and wealth constrained.[18]

From the discussion above, the next lemma follows immediately:

Lemma 1 *If only spot contracts are available, it is optimal not to include a covenant not to compete in the employment contract.*

Under spot contracting, the firm does not reward a successful employee if there is a covenant in the contract. If there is no covenant, the firm is forced to pay at least *some* reward to the successful employee (as he otherwise leaves for a competitor). Letting the employee be free to leave thus partly overcomes the commitment problem of the firm, and this is the intuition why it is optimal not to include a CNC in the contract.

2.2.3 Relational contracts

A covenant not to compete Let us start with the case where a CNC exists. Recall that under a relational contract, Firm 1 promises to pay the employee a bonus, b, if an innovation is made. Suppose that the employee expects the bonus to be paid. The optimal effort is found from the program: $\max_a U(a) = s + ab - \gamma a^2$, which leads to $a(b) = b/(2\gamma)$. The firm offers the employee the wage that just satisfies his participation constraint: $s(b) = -b^2/(4\gamma)$. (Note that sofar the role of b is precisely the same as ϕ in the analysis above.) The per period payoff of the firm, as a function of b, is:

$$V_{CNC,R}(b) = a(b)(1-b) - s(b) = \frac{b(1-b)}{2\gamma} + \frac{b^2}{4\gamma} = \frac{b(2-b)}{4\gamma}$$

However, the key issue here is to understand whether the implicit contract is self-sustainable or not. Indeed, $V_{CNC,R}(b)$ can be the payoff only if the employee anticipates that the firm will pay the bonus. Else, he makes zero effort. Let us look then at the incentive constraint of the firm. The firm, after observing an innovation, has to compare the payoffs from paying the bonus and from reneging.

We consider an equilibrium sustained by 'grim' trigger strategies. We assume that if the firm deviates and chooses not to pay the bonus, it loses its reputation not only with the current employee but also with all potential employees: in any future period, an employee will accept only spot contracts.[19,20] After a deviation, the firm has thus to use spot contracts in all future. It prefers then to give up the covenant, as this gives a

[18] If either one of these two assumptions is relaxed, some of the monetary rents will go to the employee. See section 4.2.

[19] Hyde brings an illustration of such a reputation mechanism at play (http://www.andromeda.rutgers.edu/~hyde/WEALTH3.htm). Intel sued in 1989 Chan, an engineer, for having misappropriated some of Intel's intellectual property related to the 80387 mathematical co-processor. This was a highly unusual step in Silicon Valley, and was perceived as unfair by the community of research engineers. As a result, Intel suffered serious recruitment problems. Apparently, this led Intel to abandon the practice of suing departing employees.

[20] If one is not comfortable with the hypothesis of reputational effects in the labor market, one can think that because of lock-in effects there can be a relationship only between the firm and a particular employee. After not receiving the bonus, this employee will not be willing to enter a relational contract any longer.

higher payoff under spot contracting.[21] Therefore, the firm's incentive constraint (IC) is determined by the following condition:

$$(1-b)+\frac{V_{CNC,R}(b)}{r}\geq 1+\frac{V^*_{\emptyset,S}}{r},$$

where the left hand side (LHS) are the profits of the firm if it pays the bonus, and the right hand side (RHS) are the profits if it deviates, pays no bonus, and continues with spot contracting and no CNC. Therefore, the problem of the firm is (after rewriting the IC):

$$\max_b V_{CNC,R}(b) \quad \text{subject to:} \quad V_{CNC,R}(b)\geq rb+V^*_{\emptyset,S}$$

The objective function finds its maximum in the unconstrained problem for $b^{fb}=1$ (that leads to the first best effort $a^{fb}=1/2\gamma$). However, the constraint might be binding, or there could be no value of b satisfying it. The following proposition summarizes the solution of this program:

Lemma 2 *(Relational contract and a covenant not to compete)*
For $1/2\geq\phi$, the optimal relational contract with a covenant is characterized as follows:
i. If $r\leq\frac{(1-\phi)^2}{4\gamma}\equiv\widehat{r}_{fb}$, then $b^*=1$ (the relational contract attains first best).
ii. If $\widehat{r}_{fb}<r\leq\frac{1-\sqrt{\phi(2-\phi)}}{2\gamma}\equiv\widehat{r}_o$, then $b^*=\widehat{b}=1-2\gamma r+\sqrt{(1-2\gamma r)^2-\phi(2-\phi)}$ (the relational contract attains second best).
iii. If $r>\widehat{r}_o$, then the problem has no solution (only spot contracts exist).

Proof. For $b^*=1$, the incentive constraint is $V(1)=1/(4\gamma)\geq r+\phi(2-\phi)/(4\gamma)$, which is satisfied iff. $r\leq\widehat{r}_{fb}$. For higher values of r, b^* does not satisfy the incentive constraint. Therefore, the firm chooses the highest possible value of b that satisfies the incentive constraint with equality. This is a standard second order equation, whose higher root is $\widehat{b}=1-2\gamma r+\sqrt{(1-2\gamma r)^2-\phi(2-\phi)}$. This root exists only if $(1-2\gamma r)^2-\phi(2-\phi)>0$, i.e. $r\leq\widehat{r}_o$. ■

Lemma 2 states only the optimal bonus, but the corresponding effort and fixed wage are easily derived from the incentive and participation constraint of the employee. Note that when the relational contract is feasible, the firm always prefers it over spot contracts. This can be observed from the fact that a necessary condition for the incentive constraint of the firm to hold is $V_{CNC,R}(b)\geq V^*_{\emptyset,S}$ $(>V^*_{CNC,S})$.

Observe that other things equal, the lower the discount rate r (i.e., the more weight attached to the future) the more likely that the relational contract can be sustained and lead to the first best. For intermediate values of the discount rate, a relational contract

[21] After a deviation, the firm and the employee renegotiate the contract, as the employee gets a negative pay-off under the initial contract in the continuation game following a deviation where no bonus is paid (the employee would otherwise leave). The employee has no bargaining power, and the firm chooses the spot contract that maximizes its expected profits.

can be sustained, but only the second best solution $\widehat{b}$ can be obtained. If the discount rate is too large, only the spot contracts arise and the firm gives up the covenant to increase its payoff.

The following comparative statics result are easily obtained: $\partial b^*/\partial r \leq 0$ and $\partial b^*/\partial \phi \leq 0$. If the interest rate increases, it becomes more attractive for the firm to deviate from the relational contract because future benefits from the contract (relative to spot contracting) are valued less. Therefore, the bonus has to decrease to sustain cooperation. Higher duopoly profits have a similar effect on the equilibrium bonus, as they increase the profits from deviating through $V^*_{\emptyset,S}$.

It is interesting to note that the firm is hurt by the fact that it is able to give up the CNC after reneging on the relational contract. This increases the payoff from deviating and makes it harder to sustain the more profitable relational contract.

No covenant Let us now look at the relational contract under the assumption that there is no covenant. This gives the employee the possibility to get an outside offer (but recall we assume that he cannot leave if he accepts the bonus). Everything is as above, except that the employee may threaten to leave if no bonus is paid or it is rejected. The outside offer is ϕ. Therefore, the employee only accepts the bonus, and refrains from getting outside offers, if $b \geq \phi$. We only consider contracts where the bonus is accepted, as the contract otherwise is equivalent to a spot contract.

The incentive constraint of the firm is then:

$$(1-b) + \frac{V_{\emptyset,R}(b)}{r} \geq 1 - \phi + \frac{V^*_{\emptyset,S}}{r},$$

where the LHS are the profits if the bonus is paid, and the RHS are the profits if the firm deviates, the employee is hired at the wage ϕ, and the employment is continued under spot contracting with no CNC.

Proceeding as above, the problem of the firm is:

$$\max_b V_{\emptyset,R}(b) = V_{CNC,R}(b) = \frac{b(2-b)}{4\gamma} \quad \text{subject to:} \quad V_{\emptyset,R}(b) \geq rb - r\phi + V^*_{\emptyset,S} \textit{ and } b \geq \phi.$$

The following proposition summarizes the solutions of the firm's program:

Lemma 3 *(Relational contract and no covenant not to compete)*
For $1/2 \geq \phi$, the optimal relational contract without a covenant is characterized as follows:
i. If $r \leq \frac{(1-\phi)}{4\gamma} \equiv \widetilde{r}_{fb}$, then $b^* = 1$ (the relational contract attains first best).
ii. If $\widetilde{r}_{fb} < r \leq \frac{(1-\phi)}{2\gamma} \equiv \widetilde{r}_o$, then $b^* = \widehat{b} = 2 - \phi - 4\gamma r$ (the relational contract attains second best)
iii. If $r > \widetilde{r}_o$, then the problem has no solution (only spot contracts exist).

Proof. At $b^* = 1$, the incentive constraint is: $V_{\emptyset,R}(1) = 1/4\gamma \geq r - r\phi + \phi(2-\phi)/(4\gamma)$, which is satisfied iff $r \leq \widetilde{r}_{fb}$. For higher values of r, the incentive constraint binds and the firm chooses the highest bonus solving: $b/(2\gamma) - b^2/(4\gamma) = rb - r\phi + \phi(2-\phi)/(4\gamma)$, whence $\widehat{b} = 2 - \phi - 4\gamma r$. Since we require that $b \geq \phi$, it must be that $r \leq (1-\phi)/(2\gamma)$. For higher values of r, there is no solution to the constrained program. ■

We have as above, and for the same reasons, $\partial b^*/\partial r \leq 0$ and $\partial b^*/\partial \phi \leq 0$. Comparing the incentive constraint of the firm with and without a CNC, we see that the constraint is looser if there is no covenant (the only difference between the two constraints is ϕ that is substracted on the RHS when there is no CNC). The absence of a covenant endows the employee with the threat to leave the firm. This decreases the payoff of the firm from deviating, so a relational contract can be sustained for a larger region of parameters and with higher powered incentives. The next lemma shows this formally.

Lemma 4 *For $1/2 \geq \phi$, the region of parameters for which a relational contract exists is larger if there is no covenant not to compete included in the employment contract. Furthermore, whenever a relational contract exists both with and without a covenant, both the profits of the firm and the effort of the employee are (weakly) greater with no covenant.*

Proof. To prove this proposition, we just have to compare the results obtained in Lemma 2 and 3. We start by comparing the threshold values. It is straightforward to show that $\widehat{r}_{fb} < \widetilde{r}_{fb}$ and $\widehat{r}_o < \widetilde{r}_o$. Therefore, if $r \in (0, \widehat{r}_{fb}]$, the profits are the same with and without a covenant, as the first best bonus can be implemented. If $(\widetilde{r}_o, \infty)$, no relational contract exists (and Lemma 1 establishes that profits are higher if there is no covenant). If $r \in (\widehat{r}_{fb}, \widetilde{r}_{fb}]$, it is optimal to have no covenant as this is the only way that b^{fb} can be implemented. Similarly, if $r \in (\widehat{r}_o, \widetilde{r}_o]$, it is optimal not to have a covenant as there otherwise exists no relational contract. Finally, consider $r \in (\widetilde{r}_{fb}, \widehat{r}_o]$ where a second best relational contract exists with and without a covenant. Here, the equilibrium effort under the covenant ($\widehat{b}_c$) is lower than without the covenant ($\widehat{b}_{nc}$): $\widehat{b}_c = 1 - 2\gamma r + \sqrt{(1-2\gamma r)^2 - \phi(2-\phi)} < \widehat{b}_{nc} = 2 - \phi - 4\gamma r$. Since $V_{i,R}(b)$ is increasing in b for $b < 1$, it is optimal not to have a covenant in this region. ■

Combining the previous results, we obtain the following proposition, which is one of the main results of the paper:

Proposition 1 *When the innovation depends only on the employee's effort, it is always (weakly) better for the firm not to include a covenant not to compete in the employment contract.*

Proof. There are three situations possible: 1) only spot contracting is possible whether or not a covenant is included ($r \in (\widetilde{r}_o, \infty)$); 2) a relational contract exists only if there is no covenant ($r \in (\widehat{r}_o, \widetilde{r}_o]$); and 3) a relational contract exists with and without a covenant ($r \in (0, \widehat{r}_o]$). Since a relational contract always dominates spot contracts when it exists, the proof follows directly from Lemma 1 and 1. ■

This intuition behind this result is, as explained above, that having no covenant alleviates the commitment problem of the firm. The firm would like to commit to rewarding the employee for innovating but doing so is difficult. Under spot contracting, the only way to credibly promise to reward a successful employee is not to include a CNC. Under relational contracting, the commitment problem is less severe, as the threat of reversion to spot contracting makes it costly for the firm to renege on its (implicit) promises. However, even in a relational contract, it is (weakly) better not to include a CNC, as it relaxes the incentive constraint of the firm by increasing the cost of deviating.

3 Two-sided investments

In this section, we extend the analysis by considering the case where not only the employee but also the employer invests in creating the innovation. We therefore modify slightly the game analyzed sofar by assuming that in the second stage of each period the firm also makes an investment, I. More specifically, we assume that the probability of an innovation is $\lambda a+(1-\lambda)I$ where a and I are the investments of the employee and the firm, respectively. λ is thus a measure of how important the employee's investment is relative to the firm's. In the extreme cases, if $\lambda = 1$, only the employee's investment matters, whereas if $\lambda = 0$ only the firm's investment matters. The cost of investing is given by $\gamma(i)^2$ $(i = a, I)$ for both agents. We assume that $\phi \leq \frac{1}{2}$ and that the employee is not credit constrained.

3.1 Benchmark: first best

We first determine the optimal contract when it is possible to contract upon the worker's contribution to the innovation, so the firm can commit to paying b if he is successful. In this case, at the innovation stage the employee solves $\max_a \left\{(\lambda a + (1-\lambda)I)b - \gamma(a)^2 + s\right\}$, which leads to the effort $a(b) = \lambda b/(2\gamma)$; the firm solves $\max_I \left\{(\lambda a + (1-\lambda)I)(1-b) - \gamma(I)^2 - s\right\}$, resulting in the investment $I(b) = (1-\lambda)(1-b)/(2\gamma)$.

The firm maximizes its profit subject to the participation constraint of the employee: $\max_{b,s} \left\{(\lambda a(b) + (1-\lambda)I(b))(1-b) - \gamma(I(b))^2 - s\right\}$, subject to $s \geq \gamma(a(b))^2 - (\lambda a(b) + (1-\lambda)I(b))\, b$. After substituting and noting that the participation constraint will bind, this can be rewritten as:

$$\max_b V(b) \equiv \left\{\frac{\lambda^2 b(2-b)}{4\gamma} + \frac{(1-\lambda)^2(1-b^2)}{4\gamma}\right\}.$$

Solving this problem, we obtain:

$$b^{fb}(\lambda) = \frac{\lambda^2}{\lambda^2 + (1-\lambda)^2}.$$

It can be checked that the second order condition is satisfied, so b^{fb} is a global maximum. It is not possible to increase the incentives of the firm and the employee at the same time, as a higher bonus to the employee leads to lower profits for the firm. The optimal bonus has thus to trade-off the incentives of the firm and the employee. b^{fb} is increasing in λ, because the incentives of the employee become more important (relative to the firm's) when the employee contributes more to the innovation.

3.2 Spot contracts

3.2.1 Covenant not to compete

Suppose first that there is a CNC, so the employee cannot leave following an innovation. Under spot contracting, the firm does not pay the employee extra if there is an innovation. Therefore, as in the base model, we have: $a = s = 0$. The firm receives profits of 1 if it innovates. The problem of the firm can thus be written as $\max_I V_{CNC,S} = (1-\lambda)I - \gamma(I)^2$, which results in $I = (1-\lambda)/(2\gamma)$ and $V^*_{CNC,S} = V(0) = (1-\lambda)^2/(4\gamma)$.

3.2.2 No covenant

We now turn to the case where there is no CNC. In equilibrium, the firm pays ϕ to the employee if there is an innovation to avoid him leaving. The employee makes the effort $a = \lambda\phi/(2\gamma)$, and the firm extracts all expected rents by offering $s = -\lambda^2\phi^2/(4\gamma) - (1-\lambda)^2(1-\phi)\phi/(2\gamma)$. The expected profits of the firm are: $V^*_{\emptyset,S} = \lambda^2\phi(2-\phi)/(4\gamma) + (1-\lambda)^2(1-\phi^2)/(4\gamma)$.

Comparing the profits with and without a covenant, we have the following result:

Lemma 5 *Under spot contracting, the firm chooses to have a covenant not to compete if and only if*

$$\phi \geq 2b^{fb}(\lambda).$$

Proof. Follows directly from comparing profits above. ■

In order to understand the lemma, note that the condition $\phi \geq 2b^{fb}(\lambda)$ is equivalent to $\lambda \leq \widetilde{\lambda}(\phi)$, where $\widetilde{\lambda}(\phi)$ (with $\partial\widetilde{\lambda}/\partial\phi > 0$) is implicitly given by $\phi = \frac{2\lambda^2}{\lambda^2+(1-\lambda)^2}$. In general, the firm chooses a covenant if the effort of the employee is relatively unimportant for the R&D outcome (λ low) and competition in the product market is weak (ϕ is high). In this case, the employee would be paid too high a reward for an innovation if there were no CNC, and this would destroy the (more important) incentives of the firm.[22] This result is in the spirit of Grossman and Hart (1986) showing that the residual rights of control should be owned by the party whose investment is more important.[23]

In the base model, where only the employee's effort matters for R&D ($\lambda = 1$), it is optimal to have no CNC to provide incentives to the employee. In the other extreme case where only the firm's investment matters ($\lambda = 0$), it is optimal to have a covenant, because it maximizes the incentives of the firm by minimizing the reward to the employee. (This is easily seen from Lemma 5 as $b^{fb} = 0$ for $\lambda = 0$.)

[22] Notice that $\frac{1}{2} \geq \phi \geq 2b^*$ is feasible if and only if $\lambda \leq (\sqrt{3}-1)/2$.

[23] Unlike Grossman and Hart, in this paper there is not a choice between giving the control rights to either the firm or the employee. Rather, there is a choice between giving the control rights to the firm (a covenant) or sharing them (no covenant).

3.3 Relational contracts

We now consider the possibility of relational contracts. Reassuringly, the conclusion of Lemma 5 will not change. It is optimal to include a CNC in the employment contract if and only if $\phi \geq 2b^{fb}$. However, the analysis of relational contracts with two-sided investment is rather long, so the reader may consider skipping it at a first reading.

3.3.1 A covenant not to compete

In the analysis, we need to consider $\phi < 2b^{fb}$ and $\phi \geq 2b^{fb}$ separately, as the spot contract that the firm would choose after reneging on the relational contract is different (see Lemma 5).

A covenant, for $\phi < 2b^{fb}$ The problem of the firm is $\max_{b,s} V(b,s) = \{\lambda^2 b(1-b)/(2\gamma) + (1-\lambda)^2(1-b)^2/(4\gamma) - s\}$, subject to the employee's participation constraint $\lambda^2 b^2/(4\gamma) + (1-\lambda)^2(1-b)b/(2\gamma) + s \geq 0$ and the firm's incentive constraint $\left(V(b,s) - V^*_{\emptyset,S}\right)/r \geq b$. This can be rewritten as:

$$\max_b V(b) \quad \text{subject to:} \quad \frac{1}{r}\left(V(b) - V^*_{\emptyset,S}\right) \geq b \tag{3}$$

Except for both parties investing, the problem of the firm is the same as in the base model. Solving the program, we obtain:

Lemma 6 *(Relational contract and a covenant not to compete)*
For $\phi \leq 2b^{fb}$, the optimal relational contract with a covenant is characterized as follows:
i. If $r \leq \frac{\lambda^2}{4\gamma}\left(1 - \frac{\phi}{b^{fb}}\right)^2 \equiv r_{fb}$, then $b^* = b^{fb}$ (the relational contract attains first best).
ii. If $r_{fb} < r \leq \frac{\lambda^2}{2\gamma}\left(1 - \sqrt{\frac{\phi}{b^{fb}}(2 - \frac{\phi}{b^{fb}})}\right) \equiv r_{sb}$, then
$b^* = b^{sb} \equiv b^{fb}\left[1 - \frac{1}{\lambda^2}\left(2\gamma r - \lambda^2\sqrt{\frac{\phi}{b^{fb}}(2 - \frac{\phi}{b^{fb}}) + \left(1 - \frac{2\gamma r}{\lambda^2}\right)^2}\right)\right]$ (the relational contract attains second best).
iii. If $r > r_{sb}$, then the problem has no solution (only spot contracts exist).

Proof. In appendix. ■

As expected, a decrease in the interest rate and a decrease in ϕ make the relational contract more likely to be sustained, as they make less attractive for the firm to renege on the contract and continue the relation with a spot contract (and no covenant). One can check that for $\lambda = 1$ (which implies $b^{fb} = 1$), Lemma 6 coincides with Lemma 2 of section 2.

A covenant, for $\phi \geq 2b^{fb}$ In this case, the only difference is that after a deviation the firm would keep the covenant. Hence, its program is:

$$\max_b V(b) \quad \text{subject to:} \quad \frac{1}{r}\left(V(b) - V^*_{CNC,S}\right) \geq b. \tag{4}$$

Lemma 7 *(Relational contract and a covenant not to compete)*
For $\phi > 2b^{fb}$, the optimal relational contract with a covenant is characterized as follows:
i. If $r \leq \frac{\lambda^2}{4\gamma} \equiv r_{fb}$, then $b^* = b^{fb}$ (the relational contract attains first best).
ii. If $r_{fb} < r \leq \frac{\lambda^2}{2\gamma} \equiv r_{sb}$, then $b^* = b^{sb} \equiv 2b^{fb}\left(1 - \frac{2\gamma r}{\lambda^2}\right)$ (the relational contract attains second best).
iii. If $r > r_{sb}$, then the problem has no solution (only spot contracts exist).

Proof. In appendix. ■

Notice that ϕ does not enter the conditions in Lemma 7: the firm would keep the CNC even after reneging on the contract, so ϕ does not affect the profits from reneging.

3.3.2 No covenant

Like in the previous case, we distinguish between $\phi \leq 2b^{fb}$ and $\phi > 2b^{fb}$.

No covenant, for $\phi \leq 2b^{fb}$ We have to consider two sub-cases here. The first one is the case where $\phi \leq b^{fb}$. Here, a relational contract can only be sustained if $b > \phi$, as a spot contract would otherwise do better. The second one is the case where $\phi > b^{fb}$. In this case, the optimal bonus must be such $b < \phi$, which will raise some new issues: since the outside offer is higher than the bonus. Let us start with the first sub-case.

No covenant, for $\phi \leq b^{fb}$ The problem facing the firm is similar to (3), except for the incentive constraint, as the firm has to pay ϕ to keep the employee after reneging on the contract:

$$\max_b V(b) \quad \text{subject to:} \quad \frac{1}{r}\left(V(b) - V^*_{\emptyset,S}\right) \geq b - \phi. \tag{5}$$

The next lemma states the results in this case:

Lemma 8 *(Relational contract and no covenant not to compete)*
For $\phi \leq b^{fb}$, the optimal relational contract without a covenant is characterized as follows:
i. If $r \leq \frac{\lambda^2}{4\gamma}\left(1 - \frac{\phi}{b^{fb}}\right) \equiv r_{fb}$, then $b^* = b^{fb}$ (the relational contract attains first best).
ii. If $r_{fb} < r \leq \frac{b^{fb}\left(b^{fb} - \phi\right)}{2\gamma\lambda^2} \equiv r_{sb}$, then $b^* = b^{sb} \equiv 2b^{fb} - \phi - \frac{4\gamma r\lambda^2}{b^{fb}}$ (the relational contract attains second best).
iii. If $r > r_{sb}$, then the problem has no solution (only spot contracts exist).

Proof. In appendix. ■

One can check that the critical values which satisfy Lemma 8 are identical to those found in the base model in section 2 for the special case of $\lambda = 1$.

No covenant, for $b^{fb} < \phi \leq 2b^{fb}$ As anticipated above, there are new issues arising for $\phi > b^{fb}$. A relational contract is only sustainable if it allows the firm to pay a bonus that is lower than ϕ and to strike a better balance between the incentives of the firm and the employee.[24] This, however, raises the problem that the employee may leave for the rival even if offered the bonus. Indeed, if the employee earned a zero expected wage every period, as it was the case up to now, he would find it optimal to reject the bonus and take the outside offer.

The only way to implement a relational contract with $b < \phi$ is thus to ensure that the employee earns rents from staying in the relation.[25] The employee may then accept the bonus, even if the outside offer is higher, because leaving would imply giving up the future rents from the relation. Therefore, the firm offers a contract that gives rents to the employee once the relation is running. However, the firm takes away these expected rents through a time 0 payment of e from the employee to the firm.[26]

In principle, the firm could make the employee stay for any bonus by making the future rents sufficiently high. However, following the literature (e.g., MacLeod and Malcomson (1989)), we assume that both parties can terminate the relation. Paying rents to employee introduces therefore an incentive problem on the side of the firm: the firm may choose to cash-in e and afterwards terminate the relation (and continue with a spot contract).

The following lemma shows that the firm's program with the new constraints can be simplified considerably:

Lemma 9 *If $b^{fb} < \phi \leq 2b^{fb}$ and there is no CNC, the problem of the firm, when choosing the optimal relational contract, reduces to:*

$$\max_b V(b) \text{ subject to: } \frac{1}{r}\left(V(b) - V^*_{\emptyset,S}\right) \geq \phi - b. \quad (6)$$

Proof. In appendix. ■

The next lemma characterizes the optimal relational contract for $b^{fb} < \phi \leq 2b^{fb}$:

Lemma 10 *(Relational contract and no covenant not to compete)*
For $b^{fb} < \phi \leq 2b^{fb}$, the optimal relational contract without a covenant is characterized as follows:
i. If $r \leq \frac{\lambda^2}{4\gamma}\left(\frac{\phi}{b^{fb}} - 1\right) \equiv r_{fb}$, then $b^* = b^{fb}$ (the relational contract attains first best).
ii. If $r_{fb} < r \leq \frac{\lambda^2}{2\gamma}\left(\frac{\phi}{b^{fb}} - 1\right) \equiv r_{sb}$, then $b^* = b^{sb} \equiv 2b^{fb} - \phi + \frac{4\gamma r b^{fb}}{\lambda^2}$ (the relational contract attains second best).
iii. If $r > r_{sb}$, then the problem has no solution (only spot contracts exist).

Proof. In appendix. ■

[24] In the base model, it would be optimal (if incentive compatible) to make the employee the residual claimant, i.e. $b^{fb} = 1$. Therefore, the outside offer was never too high. Here, where both parties invest, this is possible. For example, if $\phi \geq b^{fb}$, the outside offer over-rewards the employee and under-rewards the firm relative to first best.

[25] Note that a bonus $b > \phi$ could not be optimal: the firm would be better off using a spot contract, which would give the employee a reward ϕ for his successful effort.

[26] In the previous cases considered, there was no problem of the employee rejecting the bonus. The contracts considered here would therefore not have lead to a more efficient outcome.

No covenant, for $\phi > 2b^{fb}$ Notice that there is no relational contract with $b > \phi$, as this would be dominated by a spot contract. To sustain a relational contract with $b < \phi$ the firm has to guarantee some rents to the employee in each period - while appropriating them at period $t = 0$. One has then to consider a larger set of constraints, like in the previous case. Fortunately, the problem of the firm simplifies to:

Lemma 11 *If $\phi > 2b^{fb}$ and there is no CNC, the problem of the firm, when choosing the optimal relational contract, reduces to:*

$$\max_b V(b) \text{ subject to: } \frac{1}{r}\left(V(b) - V^*_{CNC,S}\right) \geq \phi - b. \tag{7}$$

Proof. In appendix. ■

The following lemma summarizes the results:

Lemma 12 *(Relational contract and no covenant not to compete)*
For $\phi \geq 2b^{fb}$, the optimal relational contract without a covenant is characterized as follows:
i. If $r \leq \frac{\lambda^2}{4\gamma}\left(\frac{b^{fb}}{\phi - b^{fb}}\right) \equiv r_{fb}$, then $b^* = b^{fb}$ (the relational contract attains first best).
ii. If $r_{fb} < r \leq \frac{\lambda^2}{2\gamma}\left(\frac{\phi}{b^{fb}} - 1 - \sqrt{\frac{\phi}{b^{fb}}\left(\frac{\phi}{b^{fb}} - 2\right)}\right) \equiv r_{sb}$, then
$b^* = b^{sb} \equiv b^{fb}\left[1 - \frac{1}{\lambda^2}\left(\sqrt{\left(\lambda^2 + 2\gamma r\right)^2 - \frac{4\gamma r \lambda^2}{b^{fb}}} - 2\gamma r\right)\right]$ (the relational contract attains second best).
iii. If $r > r_{sb}$, then the problem has no solution (only spot contracts exist).

Proof. In appendix. ■

3.4 The optimal choice of a covenant

We are ready to consider the firm's choice of whether including a covenant not to compete in the contract. For $\lambda = 0$, a spot contract with a covenant achieves the first best, so there is no role for a relational contract. In the following, we thus focus on $\lambda > 0$.

First, consider $\phi \leq b^{fb}$. Under relational contracting, the firm maximizes $V(b)$. The constraint on the firm's problem depends on whether there is a covenant or not:

$$\left(V(b) - V^*_{\emptyset,S}\right)/r \geq b - \phi \text{ (no covenant), or } \left(V(b) - V^*_{\emptyset,S}\right)/r \geq b \text{ (covenant).}$$

The constraint is laxer if there is no covenant, as the firm has to compete with the rival to keep the employee if it reneges on the bonus. It follows from Lemma 6 and 8 that a relational contract is easier to sustain and is more efficient without a CNC. Furthermore, since the firm prefers no CNC also under spot contracting, it is never optimal to include a covenant in the contract.

Lemma 13 *For $\phi < b^{fb}$, it is (weakly) optimal for the firm not to include a CNC in the contract.*

Proof. In appendix. ■

Consider now $b^{fb} \leq \phi \leq 2b^{fb}$. The argument follows closely the one above. Under relational contracting, the firm maximizes $V(b)$, subject to the following constraints:

$$\left(V(b) - V^*_{\emptyset,S}\right)/r \geq \phi - b \text{ (no covenant), or } \left(V(b) - V^*_{\emptyset,S}\right)/r \geq b \text{ (covenant).}$$

It can be checked that the constraint is again laxer if there is no covenant. Hence, as for $\phi \leq b^{fb}$, the firm chooses to have no CNC:

Lemma 14 *For $b^{fb} \leq \phi \leq 2b^{fb}$, it is (weakly) optimal for the firm not to include a CNC in the contract.*

Proof. Omitted as it follows the same steps as the proof of Lemma 13. ■

The next lemma shows that it is optimal to include a CNC in the contract for $\phi \geq 2b^{fb}$. The intuition is that the outside offer drives up the bonus in the relational contract when there is no covenant (to avoid the employee leaving). The employee thus receives too strong incentives, and the firm too weak, relative to the first best.

Under the relational contract the firm chooses b to maximize the same function $V(b)$, subject to the following constraints:

$$\left(V(b) - V^*_{CNC,S}\right)/r \geq \phi - b \text{ (no covenant), or } \left(V(b) - V^*_{CNC,S}\right)/r \geq b \text{ (covenant).}$$

In this region, however, the constraint is laxer under the covenant, as $\phi - b \geq b$, so relational contracts work better. In addition, we know from Lemma 5 that with spot contracts the covenant gives the firm a higher payoff. Arguing as above, it follows that it is optimal to impose a covenantfor all interest rates.

Lemma 15 *For $\phi \geq 2b^{fb}$, it is (weakly) optimal for the firm to include a CNC in the contract.*

Proof. Omitted as it follows the same steps as the proof of Lemma 13. ■

The next proposition summarizes this rather long analysis.

Proposition 2 *It is optimal to include a CNC in the employment contract if and only if $\phi > 2b^{fb}$.*

The inclusion of relational contracts does not change the conclusion obtained under spot contracting. It is optimal to include a covenant not to compete in the contract if the employee's effort is relatively unimportant compared to the investment of the firm.

4 Robustness of the results

In this section, we relax some of the assumptions made (one at a time) in the model. To do so, we return to the base model of section 2, that allows for a simpler treatment than the general case. First, we examine the case where the efficiency effect does not hold ($\phi > \frac{1}{2}$); second, we study the case where the employee is credit constrained; third, we discuss alternative assumptions about the nature of the hiring process; fourth, we consider a variant of the model where the employee can choose among different projects; fifth, we briefly discuss the case of asymmetric information between the firms.

4.1 The efficiency effect does not hold ($\phi > \frac{1}{2}$)

Up to now, we have considered only the case where the so-called efficiency effect holds. Now, we analyze the case where $\phi > \frac{1}{2}$. Here, the outside firm has the highest valuation of the employee (said otherwise, the firm loses relatively little from letting the employee go). If the employee is free to leave, the outside firm (Firm 2) hires the employee paying a wage of $1 - \phi$. If the employee cannot leave, either because of a CNC or because it has accepted a bonus, Firm 2 gives a take-it-or-leave-it offer to Firm 1.[27] In equilibrium, Firm 2 hires the employee paying $1 - \phi$ to Firm 1. The outside firm thus always hires the employee paying $1 - \phi$. However, the payment goes to the employee only if he is free to leave. Otherwise, it goes to the firm.

Spot contracts Following an innovation, the employee receives a wage of 0 if there is a covenant and $1 - \phi$ if there is none. Therefore, the effort of the employee is 0 and $(1 - \phi)/(2\gamma)$ with and without a covenant, respectively. Proceeding as in the base model, we have:

$$V^*_{CNC,S} = 0 \text{ and } V^*_{\emptyset,S} = \frac{1 - \phi^2}{4\gamma}.$$

Hence, the firm prefers to have no CNC under spot contracting. Notice that $V^*_{\emptyset,S}$, unlike in section 2, is decreasing in ϕ. The reason is that the wage is decreasing in ϕ, which in turn decreases the effort of the employee.[28] In the limit, $\phi = 1$, the firm is not willing to pay anything, as the outside firm uses the innovation in an independent product market. Therefore, the employee receives a zero wage, also if there is no CNC, and exerts no effort.

[27] The results are robust to different specifications of the bargaining game as long as the employee earns a lower wage with a CNC than without; see discussion in next subsection.

[28] Suppose that the employee's outside option instead would be to set up his own business. Disregarding any fixed costs of starting the business, this option would have the value ϕ (i.e., the duopoly profits). For $\phi \leq 1/2$, it doesn't matter whether the outside option is to start up a business or to leave for a competitor. For $\phi > 1/2$, however, the value of the outside option is decreasing in ϕ if the employee receives an offer from a competitor whereas it is increasing if the employee can start up a new business. However, considering a start-up as the outside option would not affect the basic trade-off between having a CNC or not.

Relational contracts First, we look at relational contracts where a CNC is included. The problem of choosing the optimal contract is similar to the one in the base model. As before, the key constraint is the incentive constraint of the firm. Suppose thus that an innovation has been made. If the firm pays the bonus, the employee always accepts it, as he cannot threaten to leave for a competitor. Afterwards, the outside firm offers to pay $1-\phi$ to hire the employee. Since the employee has been paid the bonus, it is the firm that decides whether to accept or reject this offer. It will accept, as the efficiency effect does not hold. Hence, the firm lets the employee go, and hires another worker to do the production. In the present period, the firm earns: $-b+1-\phi+\phi=1-b$. The following period, the firm can start a relational contract with another worker, as it has honored the contract and kept its reputation intact. If the firm does not pay the bonus, the firm earns 1 this period (i.e., $1-\phi+\phi$). However, it has lost its reputation in the labor market and has to continue with a spot contract. The problem of the firm is thus:

$$\max_b V_{CNC,R}(b) = \frac{b(2-b)}{4\gamma} \quad \text{subject to:} \quad V_{CNC,R}(b) \geq rb + V^*_{\emptyset,S}$$

The next lemma states the solution to this program. Since the program is almost identical to the one in section 2, the proof has been left out.

Lemma 16 *(Relational contract and a covenant not to compete) For $\phi > 1/2$, the optimal relational contract with a covenant is characterized as follows:*
i. If $r \leq \frac{\phi^2}{4\gamma} \equiv \widehat{r}_{fb}$, then $b^* = 1$ (the relational contract attains first best[29]).
ii. If $\widehat{r}_{fb} < r \leq \frac{1-\sqrt{1-\phi^2}}{2\gamma} \equiv \widehat{r}_o$, then $b^* = \widehat{b} = 1 - 2\gamma r + \sqrt{(1-2\gamma r)^2 - 1 + \phi^2}$ (the relational contract attains second best)
iii. If $r > \widehat{r}_o$, then the problem has no solution (only spot contracts exist).

We now turn to contracts where there is no CNC. Consider the incentive constraint of the firm. If the firm pays the bonus, the profits are the same as with a CNC. If the firm does not pay the bonus, they are not. In this case, the firm loses the employee to the outside firm and earns duopoly profits in the present period. Afterwards, the firm continues with a spot contract because no worker in the pool is willing to accept a relational contract. The problem of the firm is thus:

$$\max_b V_{CNC,R}(b) = V_{\emptyset,R}(b) = \frac{b(2-b)}{4\gamma} \quad \text{subject to:} \quad 1 - b + \frac{V_{CNC,R}(b)}{r} \geq \phi + \frac{V^*_{\emptyset,S}}{r}$$

The firm earns monopoly profits after reneging on the bonus if there is a CNC, but only duopoly profits if there is no CNC. Therefore, the incentive constraint of the firm is laxer if there is no CNC. The study of the firm's program when there is no covenant is very similar to the program analyzed in section 2, and we omit the derivation.

[29]The first best effort is here defined as the one that maximizes the profits of Firm 1. For $\phi > 1/2$, however, Firm 2 also benefits from the innovation. The bonus that maximizes the joint profits of the two firms is thus $b = 2\phi$.

Lemma 17 *(Relational contract and no covenant) For $\phi > 1/2$, the optimal relational contract without a covenant is characterized as follows:*
i. If $r \leq \frac{\phi}{4\gamma} \equiv \widetilde{r}_{fb}$, then $b^* = 1$ (the relational contract attains first best).
ii. If $\widetilde{r}_{fb} < r \leq \frac{\phi}{2\gamma} \equiv \widetilde{r}_o$, then $b^* = \widehat{b} = 1 + \phi - 4\gamma r$ (the relational contract attains second best)
iii. If $r > \widetilde{r}_o$, then the problem has no solution (only spot contracts exist).

Armed with these results, we can now proceed to confirm the main result that we obtained in section 2:

Proposition 3 *For $\phi > 1/2$, it is always (weakly) better for the firm not to include a covenant not to compete in the employment contract.*

Proof. In appendix. ■

Proposition 3 summarizes the analysis for $\phi > 1/2$ where the employee leaves for the outside firm and technology spillovers arise. It is optimal, as it is for $\phi \leq 1/2$, not to include a CNC in the employment contract. The employee exerts a higher effort under spot contracting if there no CNC. Furthermore, it is easier to sustain a relational contracts if there is no CNC, as it is more costly for the firm to renege on the contract.

Note that for $\phi > 1/2$ job turnover arises in equilibrium, whereas it did not in the base model. Therefore, it is not the actual job turnover that matters, but rather the possibility of it.

4.2 Credit constrained employee

Throughout the paper we have assumed that the firm can extract all rents by using a negative, fixed wage. In this section, we study the case where the employee is wealth and credit constrained. In particular, we assume that the firm has to offer a wage $s \geq 0$ every period.[30] This can also be thought of as a situation where there is a minimum wage of 0. We consider only $\phi \leq 1/2$.

Spot contracts The employee receives an additional wage of ϕ if it makes an innovation and there is no CNC. Therefore, it exerts the effort $\phi/(2\gamma)$. The firm can no longer extract all rents ex-ante, but it chooses the lowest fixed wage possible, $s = 0$. The employee chooses $a = 0$, if there is a CNC, as an innovation does not increase the employee's wage bill. Hence, $s = 0$ is optimal. From this discussion follows:

$$V^*_{CNC,S} = 0 \text{ and } V^*_{\emptyset,S} = \frac{\phi(1-\phi)}{2\gamma}.$$

[30] Another possibility is that the employee is credit constrained at the beginning of the game, but not necessarily later if he is successful and earns more than the expected wage of 0. This problem is technically quite difficult, as it is not stationary, so we restrict attention to the simpler variant where $s \geq 0$ every period. This can be thought of as the other extreme case relative to the base model where the employee is credit constrained in any one period. Our speculation is that the results would not change qualitatively in an intermediate situation where the credit constraint depends on the history of outcomes.

Under spot contracting, it is thus optimal to have no covenant, as the employee otherwise chooses the minimal effort.

Relational contracts Suppose that there is a CNC in place. The employee is paid b if he innovates and chooses the effort $b/(2\gamma)$. The firm offers $s = 0$ to minimize the employee's rents. Therefore, the expected profits per period are $(1-b)b/(2\gamma)$. The bonus that solves the unconstrained problem of the firm is $b = 1/2$. Since the firm cannot use the fixed wage to extract the surplus of the employee, it offers a lower bonus in order to capture some of the rents created by the innovation. (Indeed, if it offered $b = 1$, which is the first best bonus when the employee is not credit constrained, it would earn zero profits). Abusing notation slightly, we denote $b^{fb} = 1/2$ the first best bonus, as it solves the firm's unconstrained problem.

The firm's incentive constraint has the same form as in the base model, so the problem of the firm can be written as:

$$\max_b V_{CNC,R}(b) = \frac{b(1-b)}{2\gamma} \quad \text{subject to:} \quad V_{CNC,R}(b) - V^*_{\emptyset,S} \geq rb.$$

The following lemma summarizes the solution to this program:

Lemma 18 *(Relational contract with a covenant and a credit constrained employee) For $1/2 \geq \phi$, the optimal relational contract with a covenant is characterized as follows:*
i. If $r \leq \frac{(1-2\phi)^2}{4\gamma} \equiv \widehat{r}_{fb}$, then $b^* = 1/2$ (the relational contract attains first best given the credit constraint).
ii. If $r \leq \frac{1-2\sqrt{\phi(1-\phi)}}{2\gamma} \equiv \widehat{r}_o$, then $b^* = \widehat{b}_o = \left(1 - 2\gamma r + \sqrt{(1-2\gamma r)^2 - 4\phi(2-\phi)}\right)/2$ (the relational contract attains second best).
iii. If $r > \widehat{r}_o$, then the problem has no solution (only spot contracts exist).

If there is no covenant, it is costlier to renege on the bonus, as the firm has to pay ϕ to keep the employee. Therefore, the problem of the firm is:

$$\max_b V_{CNC,R}(b) = \frac{b(1-b)}{2\gamma} \quad \text{subject to:} \quad V_{CNC,R}(b) - V^*_{\emptyset,S} \geq r(b-\phi).$$

The solution to this program is:

Lemma 19 *(Relational contract, without covenant and with a credit constrained employee) For $1/2 \geq \phi$, the optimal relational contract without a covenant is characterized as follows:*
i. If $r \leq \frac{1-2\phi}{4\gamma} \equiv \widetilde{r}_{fb}$, then $b^* = 1/2$ (the relational contract attains first best given the credit constraint).
ii. If $r \leq \frac{1-2\phi}{2\gamma} \equiv \widetilde{r}_o$, then $\widetilde{b}_o = 1 - 2\gamma r - \phi$ (the relational contract attains second best)
iii. If $r > \widetilde{r}_o$, then the problem has no solution (only spot contracts exist).

The next proposition shows that it is optimal not to include a CNC in the employment contract. (We omit the proof because it follows the same steps as above.)

Proposition 4 *Suppose that the employee is wealth and credit constrained and $1/2 \leq \phi$. Then, it is always (weakly) better for the firm not to include a covenant not to compete in the employment contract.*

As above, the intuition is that having no covenant both relaxes the firm's incentive constraint under relational contracting and gives the employee better incentives under spot contracting. The outcome is less efficient if the employee is credit constrained, as the firm has to offer a lower bonus to capture some of the rents accruing from the innovation, but it does not change the conclusion of the base model that it is optimal not to include a CNC in the contract.

4.3 Different bargaining rules

We have sofar modeled the hiring process of the employee as a first price auction. In this section we show that our qualitative results (in particular, about the effect of CNCs) are robust to different assumptions concerning the bargaining game. We restrict attention to $\phi \leq 1/2$ and assume that the employee is not credit constrained. The effects at play are easily understood from the base model, so we keep the analysis verbal.

Under spot contracting, the bargaining game is irrelevant if there is a covenant in place. Firm 1 has the highest valuation of the employee, so there are no gains from trade to be realized. Hence, after an innovation is made, Firm 1 keeps the employee without paying anything. Foreseeing this, the employee exerts no effort and $V^*_{CNC,S} = 0$.

When there is no CNC, the bargaining rule affects the solution under spot contracting. The employee receives an outside offer of ϕ from Firm 2. However, he may try to increase his wage further by threatening to leave. If the employee leaves, both the firm and the employee receive ϕ. If, on the other hand, the employee stays, the firm earns monopoly profits of 1. Depending on the bargaining power of the two parties, the employee obtains a wage $w \in [\phi, 1-\phi]$.[31,32] The employee exerts the effort $w/(2\gamma)$, which is greater than (or equal to) the effort in the base model. The profits of the firm are also higher: $V^*_{\emptyset,S} = w(2-w)/(4\gamma) \geq \phi(2-\phi)/(4\gamma)$. The conclusion of section 2 that it is optimal to have no CNC under spot contracting holds thus a fortiori.

Under relational contracting, a different bargaining rule affects the incentive constraint of the firm. The incentive constraint is $V_{CNC,R}(b) - V^*_{\emptyset,S}(w) \geq rb$ if there is a CNC

[31] There are, as mentioned in text, other equilibria in the first price auction than the one considered. These involve: Firm 2 bidding between its own and Firm 1's evaluation of the employee (i.e., $w \in [\phi, 1-\phi]$); Firm 1 matching the bid of Firm 2. Up to now, we have ignored these equilibria, as they are in weakly dominated strategies. The analysis in this section deals with alternative bargaining rules, but it can be reinterpreted as the outcome if these other equilibria are played.

[32] We have assumed that the firm keeps the innovation if the employee leaves. In some circumstances, it may be difficult for the firm to recover the innovation (it would be, for example, very difficult to force an employee to reveal a new idea that exists only inside his head). This section can thus be interpreted as a situation where, if the employee leaves, the firm risks losing the innovation. To see this, suppose that if the employee leaves, the firm keeps the innovation only with the probability $1-\theta$. The value of the employee who has made an innovation is thus $1-(1-\theta)\phi$ for Firm 1. The value of the employee is $\theta+(1-\theta)\phi$ for Firm 2. If there is a CNC in place, Firm 1 keeps the employee paying nothing additional. If there is no CNC, Firm 1 also keeps the employee but has to pay $w(\theta) = \theta + (1-\theta)\phi > \phi$.

and $V_{\emptyset,R}(b) - V^*_{\emptyset,S}(w) \geq r(b-w)$ if there is none. A higher wage affects the incentive constraints through two channels. First, by increasing the spot market payoff, $V^*_{\emptyset,S}$, it makes the incentive constraint tighter with and without a covenant. Second, if there is no covenant, a higher wage increases the cost of keeping the employee after reneging on the bonus (w on the right hand side of the constraint). This is a countervailing effect that makes the incentive constraint slacker. In total, the incentive constraint is tighter if the wage is higher both with and without a CNC.[33] However, the relational contract without a covenant still does better than the contract with a covenant due to the second effect. A higher wage decreases the profits under relational contracting, but it does not change the relative ranking between a relational contract with and without a CNC.

Finally, proceeding as above, it can be shown that it is optimal not to include a CNC in the contract for all interest rates, because it does better both under spot and relational contracting.

4.4 Project selection

We have assumed so far that the employee decides on the effort he makes, but not on the type of project he works on. In some cases, however, he might be able to choose between different projects. This gives rise to the problem that the employee might choose a project that has a lower value for the firm but a higher value for outside firms, thus increasing his expected wage via better outside offers. This is only a problem when no covenant is in place, as the outside value of the innovation otherwise does not affect the wage. The possible bias in project selection therefore tilts the trade-off between covenants and no covenants in favor of the former.

To formalize these statements, consider the following extension of the base model of section 2. The employee can either choose to work on the 'good' project, which is the same as before, or on the 'bad' project. The bad project gives rise to monopoly profits of $1-\Delta$ for Firm 1 and $1+\Delta$ for Firm 2. The corresponding duopoly profits are $\phi(1-\Delta)$ and $\phi(1+\Delta)$. The employee chooses as before the probability of success a_i where i indicates the type project chosen, $i \in \{b(ad), g(ood)\}$. The cost of effort is $\gamma(a_i)^2$. To keep close to the base model where spillovers do not arise in equilibrium, consider the case $\phi < (1-\Delta)/2$. Here, Firm 1 retains the employee by matching his outside offer of $\phi(1+\Delta)$.

4.4.1 Spot contracts

Under spot contracting, no covenant is used in equilibrium, as the employee otherwise would make zero effort. The employee chooses the bad project because it gives the highest wage and makes the effort $a_b = \phi(1+\Delta)/(2\gamma)$. The firm has profits of $\widetilde{V}_{\phi,s} = \phi(1-\Delta^2)/(2\gamma) - \phi^2(1+\Delta)^2/(4\gamma)$. Note that $\partial\widetilde{V}_{\phi,s}/\partial\Delta < 0$, so the bad project is less profitable

[33] Consider the contract with no CNC. Following the step in previous section, it can be shown that a relational contract exists if and only if $r \leq (1-w)/2\gamma$. However, for these parameters, we have: $\partial(V_{\emptyset,R}(b) - V^*_{\emptyset,S} - r(b-w))/\partial w < 0$. Hence, the incentive constraint is tighter for $w > \phi$. The first effect thus always dominates the second.

than the good one. Therefore, relational contracts are easier to sustain when the employee can choose the bad project, because profits under spot contracting are reduced.[34]

4.4.2 Relational contracts

If the contract includes a CNC, the employee has no incentive to engage in the less productive project. The firm's problem is thus

$$\max_b V(b) \quad \text{subject to:} \quad 1 - b + V(b)/r \geq 1 + \widetilde{V}_{\phi,s}/r$$

If the employee is *not* bound by a covenant, he might wish to renege on the relational contract and choose the bad project in order to get a higher outside offer. This introduces a new incentive constraint: the employee must prefer the good project to the bad. There are two cases that we need to consider separately.

Case 1: $b \geq \phi(1 + \Delta)$ Here, the bonus is higher than the outside offer even if the employee chooses the bad project. As long as the relational contract is sustainable, the employee has no incentive to choose the bad project. Therefore, the problem of the firm is:

$$\max_b V(b) \quad \text{subject to:} \quad 1 - b + V(b)/r \geq 1 - \phi + \widetilde{V}_{\phi,s}/r.$$

We see that in this case, as in the base model, no covenant relaxes the incentive constraint of the firm. Hence, in this range of parameter values, which will be sustained by a low enough discount rate r, the firm does not choose the covenant.

Case 2: $b < \phi(1 + \Delta)$ Here, the firm cannot extract all rents from the employee in each period through the fixed wage s. If it did so, the employee would choose the bad project and earn positive rents in the present period. Instead, the firm has to devise a more sophisticated contract where the employee is left some rents in each period (enough to induce the good project), and extract all these rents ex-ante through an upfront payment e from the employee.

The firm's problem becomes:

$$\begin{aligned}
\max_{b,e,s} \{((1+r)/r)\,(b(1-b)/(2\gamma) - s) + e\} \quad \text{subject to} \quad &: \\
((1+r)/r)\left(b^2/(4\gamma) + s\right) - e \quad &\geq \quad 0 \quad (i), \\
b^2/(4\gamma) + s \quad &\geq \quad 0 \quad (ii), \\
b(1-b)/(2\gamma) - s - \widetilde{V}_{\phi,s} \quad &\geq \quad 0 \quad (iii), \\
\left(b(1-b)/(2\gamma) - s - \widetilde{V}_{\phi,s}\right)/r - (b - \phi) \quad &\geq \quad 0 \quad (iv), \\
b - \phi + \frac{1}{r}\left(b^2/(4\gamma) + s\right)/r \quad &\geq \quad 0 \quad (v), \\
((1+r)/r)(b^2/(4\gamma) + s) - (\phi^2(1+\Delta)^2/(4\gamma) + s) \quad &\geq \quad 0 \quad (vi).
\end{aligned}$$

[34] See Baker et al. (2001) for a complete analysis of spot vs. relational contracts when multi-tasking is allowed (our example is a special case of their analysis).

Lemma 9 in section 3 has already studied a very similar problem, and a discussion of the constraints can be found there. The only novelty here is constraint (vi), which makes sure that the employee prefers to continue the relational contract and choose the good project. It can be shown, proceeding as in Lemma 9, that for $\phi \leq b < \phi(1+\Delta)$ this problem reduces to the following:

$$\max_b V(b) \quad \text{subject to:} \quad 1 - b + V(b)/r \geq 1 - \phi + \left(\phi^2(1+\Delta)^2 - b^2\right)/(4\gamma) + \widetilde{V}_{\phi,s}/r.$$

It is then clear that the incentive constraint under a covenant is slacker if $-\phi + \left(\phi^2(1+\Delta)^2 - b^2\right)/(4\gamma) \geq 0$. In the interval considered, this is true for low values of b but false for high values of b. For instance, if $b = \phi$ the inequality holds, but if b is close to $\phi(1+\Delta)$ it does not.

Summarizing this analysis, we have that for low values of r where a relational contract with a high bonus can be sustained, the firm will choose *not* to have the covenant. For high values of r, the firm will also not have the covenant, as only spot contracts can be used. However, for some intermediate values of r where a relational contract can be sustained, but only with a relatively low bonus, it might be optimal to introduce a covenant to make sure that the employee works on the right project.

4.5 Asymmetric information

In the base model, we assume that both the current employer, Firm 1, and its competitor, Firm 2, perfectly observe whether the employee has come up with an innovation or not, a strong assumption that deserves some comment. First, note that we assume that the worker might leave for another firm, but we might have chosen to have him set up his own firm without upsetting the main results of the analysis, namely the comparison between covenants and no covenants (some comments to this effect have been made earlier in this section). Clearly, in the case of a start-up asymmetric information would not be an issue. Second, even without entering a formal analysis that would be demanding, we can still get some ideas about how asymmetric information could modify the analysis in the case Firm 1 and 2 compete for the worker. Suppose that in an equilibrium with asymmetric information the employee would be offered $w \in (0, \phi)$ in expected terms from Firm 2. In this case, the basic mechanism emphasized sofar would still play a role: the outside offer would induce the worker to make higher effort and would relax the commitment problem of the firm, although to a smaller extent than in the case of perfect information. It is only if Firm 2 was completely unaware of the innovation, and would be unwilling to make any offer to the employee, that there would be no difference between covenants and no covenants.

5 Conclusion

We have analyzed the role of covenants not to compete in a model where an employee's effort is not observable (i.e., there is moral hazard) and the realization of the R&D outcome is observable by all parties but not contractible.

Using this framework, we have shown that when the employee's contribution to the innovation is large enough, a covenant not to compete unambiguously reduces the employee's effort, the expected number of innovations made, and the firm's profits. This result holds good both when the contract between the firm and the employee contains only explicit elements (a spot contract) and when it contains an implicit promise of a bonus (a relational contract). The intuition is that having no covenant forces the firm to reward the employee when an innovation is made, as he otherwise walks away to a rival firm. It alleviates thus a commitment problem on the side of the firm and allows for a more profitable, higher powered incentive scheme. However, when the firm's investment is more important than the employee's, there exists a rationale for including a covenant in the contract: since it prevents the employee from leaving for a competitor, a covenant ensures the appropriability of the firm's investment and favors innovation.

Our paper suggests that not to have covenants in employment contracts might in some circumstances induce more effort, thus providing a rationale for the idea that (actual or potential) labor mobility fosters innovations. However, in our setting firms' incentives are aligned with social interest, and firms should be left free to include restrictive covenants or not. In other words, we provide no justification for a policy that prevents firms from using covenants.

Admittedly, though, our analysis does not capture some effects that covenants might have. It is conceivable that they might hinder positive externalities in the form of workers spreading knowledge from one firm to another in a way that is not internalized by employers. Such ex-post effects might be important, but we have purposely focused on the ex-ante (incentive) effects of covenants.[35] A richer setting would be needed if one was to consider both ex-ante and ex-post effects of the covenants, and carry out a full welfare analysis.

Further work might be done also along other dimensions. In this paper, we have considered the effect of CNCs on the effort of the workers, but all workers were assumed to be identical. New issues would arise if workers had different intrinsic abilities. It seems, for example, plausible that choosing not to adopt CNCs might be a screening device, as the expected value of the outside offers is greater for high ability workers with a higher probability of innovating. CNCs may also reduce the incentive to try to signal high ability in a model with career concerns. While these are interesting questions, they are outside the scope of this paper.

[35] In particular, in our model once an innovation is made spillovers would arise (or would not) independently of the covenant (although the probability of having an innovation - and therefore of having a spillover at all - does depend on the presence of the covenant).

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6 Appendix

6.1 Proof of Proposition 3

It is straightforward to check that the conditions for the relational contract to hold and to give rise to the first best are always stricter for the case where a covenant exists: $\widehat{r}_{fb} < \widetilde{r}_{fb}$, and

$\widehat{r}_o < \widetilde{r}_o$. This implies that: (a) When the first best is attained under a covenant, it is attained under a no covenant regime as well: both regimes give rise to the same effort levels and profits. (b) There are parameter values where only the second best is attained under a covenant whereas without a covenant a first best is attained: under the latter regime effort and profit are higher. (c) When the second best is attained under a covenant, it is attained under a no covenant regime as well, but the equilibrium effort under the covenant $(\widehat{b}_o)$ is lower than without the covenant $(\widetilde{b}_o)$: : $\widehat{b}_c = 1-2\gamma r+\sqrt{(1-2\gamma r)^2 - 1 + \phi^2} < \widetilde{b}_o = 1-2\gamma r+\sqrt{(1-2\gamma r)^2 - (1-\phi)(1+\phi-4\gamma r)}$. Since $V(b)$ is increasing for $b < 1$, profit are also higher when a covenant does not exist. (d) There are parameter values where only a fixed wage contract can be attained under a covenant whereas without a covenant a second best relational contract is attained. Since the latter achieves positive effort and profit levels, they are higher than under the former, where effort and profit are zero. (e) There are parameters such that only spot contracts exist, with and without a CNC. Here, as shown in the main text, it is optimal to have no CNC.

6.2 Proof of Lemma 18

The IC constraint is satisfied for $b^* = 1/2$ iff. $r \leq \widehat{r}_1$. For $r > \widehat{r}_1$, the optimal bonus is the highest root that solves the IC constraint with equality as it is closest to $1/2$. This gives $\widehat{b}_0 = \left(1 - 2\gamma r + \sqrt{(1-2\gamma r)^2 - 4\phi(1-\phi)}\right)/2$. This root exists only if $r \leq \widehat{r}_0$.

6.3 Proof of Lemma 19

The IC constraint is satisfied for $b^* = 1/2$ iff. $r \leq \widetilde{r}_1$. For $r > \widetilde{r}_1$, the optimal bonus is the highest root that solves the IC constraint with equality as it is closest to $1/2$. This gives $\widetilde{b}_o = 1 - 2\gamma r - \phi$. This root exists only if $r \leq \widehat{r}_0$.

6.4 Proof of Proposition 4

It is straightforward to check that the conditions for the relational contract to hold and to give rise to the first best are always stricter for the case where a covenant exists: $\widehat{r}_{fb} < \widetilde{r}_{fb}$, and $\widehat{r}_o < \widetilde{r}_o$. This implies that: (a) When the first best is attained under a covenant, it is attained under a no covenant regime as well: both regimes give rise to the same effort levels and profits. (b) There are parameter values where only the second best is attained under a covenant whereas without a covenant a first best is attained: under the latter regime effort and profit are higher. (c) When the second best is attained under a covenant, it is attained under a no covenant regime as well, but the equilibrium effort under the covenant $(\widehat{b}_o)$ is lower than without the covenant $(\widetilde{b}_o)$: $\widehat{b}_o = \left(1 - 2\gamma r + \sqrt{(1-2\gamma r)^2 - 4\phi(2-\phi)}\right)/2 < \widetilde{b}_o = 1 - 2\gamma r - \phi$. Since $V(b)$ is increasing for $b < 1/2$, profit are also higher when a covenant does not exist. (d) There are parameter values where only a fixed wage contract can be attained under a covenant whereas without a covenant a second best relational contract is attained. Since the latter achieves positive effort and profit levels, they are higher than under the former, where effort and profit are zero. (e) There are parameters such that only spot contracts exist, with and without a CNC. Here, as shown in the main text, it is optimal to have no CNC.

6.5 Proof of of Lemma 6.

For $b^* = b^{fb}$, the incentive constraint is $V(b^{fb}) = b^2(\lambda^2/b^{fb}) + \phi\left(\phi\lambda^2/b^{fb} - 2\lambda^2\right) + 2b\lambda^2 \geq 4\gamma br$ (since $\lambda^2 + (1-\lambda)^2 = 1 - 2\lambda + 2\lambda^2 = \lambda^2/b^{fb}$) which is satisfied iff. $r \leq r_{fb}$. For higher values of r, b^* does not satisfy the incentive constraint. Therefore, the firm chooses the highest possible value of b that satisfies the incentive constraint with equality. This is a standard second order equation, whose higher root is b^{sb}. This root exists only if $r \leq r_{sb}$.

6.6 Proof of Lemma 7

For $b^* = b^{fb}$, the incentive constraint is $V(b^{fb}) = -b^2(1-\lambda)^2 + b\lambda^2(2-b) \geq 4\gamma br$, which is satisfied iff. $r \leq r_{fb}$. For higher values of r, the firm chooses the highest b that satisfies the incentive constraint with equality, that is b^{sb}. This root exists only if $r \leq r_{sb}$.

6.6.1 Proof of Lemma 8

For $b^* = b^{fb}$, the incentive constraint is $V(b^{fb}) = b^2(\lambda^2/b^{fb}) + \phi\left(\phi\lambda^2/b^{fb} - 2\lambda^2\right) + 2b\lambda^2 \geq 4\gamma br - 4\gamma\phi r$, which is satisfied iff. $r \leq r_{fb}$. For higher values of r, the firm chooses the highest b that satisfies the incentive constraint with equality, which is b^{sb}. Note that it must be $b^{sb} \geq \phi$, which leads to $r \leq r_{sb}$.

6.7 Proof of Lemma 9

The firm's problem with these new constraints is:

$$\max_{b,e,s}\left\{\frac{1+r}{r}\left(\frac{\lambda^2 b(1-b)}{2\gamma} + \frac{(1-\lambda)^2(1-b)^2}{4\gamma} - s\right) + e\right\} \tag{8}$$

subject to:

$$\begin{aligned}
\frac{1+r}{r}\left(\frac{\lambda^2 b^2}{4\gamma} + \frac{(1-\lambda)^2(1-b)b}{2\gamma} + s\right) - e &\geq 0 \; (i)\\
\frac{\lambda^2 b^2}{4\gamma} + \frac{(1-\lambda)^2(1-b)b}{2\gamma} + s &\geq 0 \; (ii)\\
\frac{\lambda^2 b(1-b)}{2\gamma} + \frac{(1-\lambda)^2(1-b)^2}{4\gamma} - s - V^*_{\emptyset,S} &\geq 0 \; (iii)\\
\frac{1}{r}\left(\frac{\lambda^2 b(1-b)}{2\gamma} + \frac{(1-\lambda)^2(1-b)^2}{4\gamma} - s - V^*_{\emptyset,S}\right) &\geq b-\phi \; (iv)\\
b - \phi + \frac{1}{r}\left(\frac{\lambda^2 b^2}{4\gamma} + \frac{(1-\lambda)^2(1-b)b}{2\gamma} + s\right) &\geq 0 \; (v)
\end{aligned}$$

Constraint (i) and (ii) ensure the participation of the employee at time 0 and at time $t > 0$, respectively. Constraint (iii) takes care that the firm does not terminate the relation once it is running. Finally, constraint (iv) and (v) make sure that the firm offers the bonus once an innovation is made and that the bonus is accepted by the employee. We have left out the time 0 participation constraint of the firm, as it is always satisfied.

In principle, the bonus could be higher or lower than ϕ. However, $b > \phi$ cannot be optimal as the firm would enjoy higher profit under a spot contract. Therefore, we can restrict our attention to $b < \phi$.

One can check that (i) has to bind to ensure period 1 participation by the worker. The firm's problem can then be written as: $\max_b V(b)$ subject to (ii)-(v). First notice that $b < \phi$ and (v) imply that (ii) is satisfied. Furthermore, $b < \phi$ and (iii) imply that (iv) is satisfied. Thus, we only need to consider constraint (iii) and (v). Denote by $s_i(b)$ the s that solves constraint (roman) number i with equality as function of b. A candidate b is feasible if and only if there exists an s such that (iii) and (v) are satisfied. This is the case if and only if $s_5(b) \leq s_3(b)$, which simplifies to the constraint in Lemma 9.

6.8 Proof of Lemma 10

For $b^* = b^{fb}$, the incentive constraint is $V(b^{fb}) \geq 4\gamma\phi r - 4\gamma br$, which is satisfied iff. $r \leq r_{fb}$. For higher values of r, the firm chooses the lowest b that satisfies the incentive constraint with equality, which is b^{sb}. Note that it must be $b^{sb} \leq \phi$, which leads to $r \leq r_{sb}$.

6.9 Proof of Lemma 11

The firm's problem is the same as in Lemma (8), the only difference being constraints (iii) and (iv), which are:

$$\begin{aligned} \frac{\lambda^2 b(1-b)}{2\gamma} + \frac{(1-\lambda)^2(1-b)^2}{4\gamma} - s - \frac{(1-\lambda)^2}{4\gamma} &\geq 0 \text{ (iii')}, \\ \frac{1}{r}\left(\frac{\lambda^2 b(1-b)}{2\gamma} + \frac{(1-\lambda)^2(1-b)^2}{4\gamma} - s - \frac{(1-\lambda)^2}{4\gamma}\right) &\geq b - \phi \text{ (iv')}, \end{aligned}$$

as the firm chooses a CNC under spot contracting. Arguing as in the proof of Lemma 9, it can be shown that constraint (i) binds whereas (ii) and (iv') do not. Using (i), (iii'), and (v), the problem reduces to $\max_b V(b)$ st. $\frac{1}{r}(V(b) - V(\phi)) \geq \phi - b$.

6.10 Proof of Lemma 12

For $b^* = b^{fb}$, the incentive constraint $V(b^{fb}) \geq 4\gamma\phi r - 4\gamma br$, which is satisfied iff. $r \leq r_{fb}$. For higher values of r, the firm chooses the lowest value of b that satisfies the incentive constraint with equality. This is a standard second order equation, whose lower root is b^{sb}. This root exists only if $r \leq r_{sb}$.

6.11 Proof of Lemma 13

For $r > \frac{b^{fb}(b^{fb}-\phi)}{2\gamma\lambda^2}$, only spot contracts exist, and Lemma 5 establish that no covenants are better in this region of the parameters' space. For $\frac{b^{fb}(b^{fb}-\phi)}{2\gamma\lambda^2} \geq r > \frac{\lambda^2}{2\gamma}\left(1 - \sqrt{\frac{\phi}{b^{fb}}(2 - \frac{\phi}{b^{fb}})}\right)$ a second best relational contract is attained without the covenant, which is better than the spot contract under the covenant. For $\frac{\lambda^2}{2\gamma}\left(1-\sqrt{\frac{\phi}{b^{fb}}(2-\frac{\phi}{b^{fb}})}\right) \geq r > \frac{\lambda^2}{4\gamma}(1-\frac{\phi}{b^{fb}})$ relational contracts exist in both regimes, but a higher bonus is attained without covenant. For $\frac{\lambda^2}{4\gamma}(1-\frac{\phi}{b^{fb}}) \geq r > \frac{\lambda^2}{4\gamma}(1-\frac{\phi}{b^{fb}})^2$ without covenant the first best is attained, whereas under the covenant only a second best is. Finally, if $r \leq \frac{\lambda^2}{4\gamma}(1-\frac{\phi}{b^{fb}})^2$ the two regimes are equivalent as they both achieve the first best under the relational contract.