Control Rights Over Intellectual Property[1]

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Abstract

We consider an incomplete contracting model of bilateral trade in intellectual property (IP) with sequential investments in its quality and financial constraints. A financially-constrained inventor invests in an idea which she then sells to the buyer; the buyer in turn invests in developing this idea into a marketable product. We propose a novel formulation of the control rights of an IP buyer, over his financially-constrained IP seller. We do not assume alienability of the inventor's ideas; the control is defined as ex ante prescribed prohibition on ex interim financial contracting with third parties. We show that such an agreement strengthens the seller's ex ante incentives to invest in the quality of her product which is to be traded at the interim stage. The enforcement of this control right is credible, or renegotiation-proof, only for the controlling buyer (a downstream user of the IP), and not for other partners of the researchers, such as independent Venture Capitalists. We thereby obtain a rationale for a key incremental role of Corporate Venturing, in promoting innovative activities.

JEL Codes: D23, K12, O32.

1 Introduction

In this paper, we develop a novel concept of control rights in a setup where parties trade in intellectual property. In this case, it is hard to apply the conventional definition of control rights and ownership based on the incomplete contract theory. The latter (Hart, 1996) considers a situation where the trading parties can make relationship-specific investment in human capital which is complementary to physical assets. The key assumption is that the parties can allocate ownership rights over these assets. The owner of the asset effectively has an option of taking away the asset and trading with a third party; this would make worthless the original counterpart's investment (which is complementary to the asset). Therefore property rights for the asset provide the owner with a stronger ex post bargaining position, and therefore a better control over the distribution of the ex post surplus. Allocation of ownership works especially well if the parties invest sequentially. Noldeke and Schmidt (1998) show that in this case, contingent ownership structures (such as options to own including buyout options, warrants, and convertible securities) help to implement the first best investment outcomes.

This argument is not applicable to the trade in intellectual property. As there are no physical assets, and human capital is not alienable, the traditional approach to understanding the value of ownership and control cannot work. Yet, in reality we do observe non-trivial choices of control rights even in the case of intellectual property. Some inventors start to work on a project on their own and contract with venture capitalists after their initial investment is made. Some innovative ideas however are created and developed through so called Corporate Venturing. Here, the inventors work within a corporation that tries to emulate the venture capital market in-house.[1] The classical case of such corporate venturing is the Xerox Technology Ventures (see Hunt and Lerner, 1995, and Chesbrough, 2002).[2] In 1988,

[1] In terms of Dushnitsky (2006), we focus on internal corporate venturing – rather than the situation of the "corporate venture capital" where an established company acts as a late-stage equity investor in an entrepreneurial venture. In terms of our model, the arm-length corporate venture capital is equivalent to independent venture capital. There are certainly many intermediate scenarios where an independent inventor enters a relationship with a corporate venture capital unit in at an early stage with the structure of the relationship similar to that of internal corporate venturing.

[2] While having become a canonical example of a corporate venture fund, the Xerox Technology Ventures was not the first or largest among those. The first corporate venture funds started in 1960s; according to the history of corporate venture in Gompers and Lerner (2004), in the late 1960s and early 1970s "more

Xerox Chairman David Kearns committed $30 million to invest in promising technologies developed within Xerox; and in the next 8 years, Xerox Technology Ventures invested in more than a dozen companies, two of which (Documentum and DSC) were significant financial successes. Even though the fund was dissolved in 1996, two years before the ten-year period Xerox has committed to, the financial returns exceeded those of comparable independent venture capitalists.

The corporate venturing arrangement is similar to Hart's vertical integration where the potential buyer has control over the seller via owning physical assets. How does the choice of the vertical integration mode matter for incentives to invest in the case of such an intangible asset as knowledge? In this paper, we develop a consistent (and empirically relevant) concept of control rights over intellectual property. Like in Noldeke and Schmidt (1998), we consider a model with sequential investments. In the first stage, the seller (an inventor) invests in generating an idea. In the second stage, this idea can be developed into a marketable product by the buyer.

Our model has three specific features that are characteristic for the trade in ideas. Firstly, ideas are non-rival. Even after an idea is sold by the inventor, the seller continues to have it. Therefore there is an issue whether the seller will sell the idea to an alternative buyer who will then undermine the original buyer's monopoly in using the idea. Secondly, there is only a limited excludability. It is very hard for the inventor to prevent the leakage of the idea to the public – therefore undermining her control over the sales. Already by describing the idea to a potential buyer, the inventor gives away a certain share of the idea's value. We assume that there is a patent system that may partially address this problem. Yet, getting a patent also leaks the description of the idea to the public domain. The third key ingredient is the inventor's financial constraint. Most inventors lack funds to develop their ideas into marketable products. The choice of the control rights is limited to independent venture or corporate venturing; the control rights over the buyer of the knowledge cannot be assigned to the inventor.[3]

than 25 percent of the Fortune 500 firms attempted corporate venture programs." The interest to corporate venturing reemerged again in mid-80s and then again in mid-90s when corporate venture funds constituted about 12 percent of total venture capital pool.

[3]Both modes–development of ideas outside or within the downstream firms–are common in practice. For example, the large pharmaceutical companies now receive a substantial part of revenue (about half, Wood and Mackenzie, 2004) from the development of drug ideas that were outsourced, or licensed from external

In this setting, Corporate Venturing matters. We do not assume that the employer can force the employee to sell the idea on the terms the employer prefers. Unlike Aghion and Tirole (1994), we do not make such an assumption; this would be equivalent to assuming the alienability of human capital. We do allow for the employee-inventor being able to sell the idea secretly to an alternative buyer. Instead, we assume that the employer can control (and veto) the inventor's financial contracting with outside venture capitalists. We show that such veto power can affect the structure of the sale and therefore the split of the trade surplus – generating greater share of the surplus for inventors with more valuable ideas.

By agreeing to the vertical integration (Corporate Venturing), the inventor ex ante agrees to constraining her choice of the structure of the ex post sale of her ideas. This certainly reduces her payoff in certain outcomes and therefore matters for her ex ante incentives to invent. In particular, the inventor invests in projects that are less likely to end up in such outcomes. Reallocation of control rights creates the trade-off between ex ante inefficiencies and ex post inefficiencies (the latter arise whenever an outside financing would be more efficient in terms of the global welfare). We show that whenever the control is shifted to the buyer of the idea, the ex post surplus is reduced but the inventor's incentives to invest may be strengthened so much that Corporate Venturing is still preferred in equilibrium. Also, because of the inventor's financial constraints, Corporate Venturing is renegotiation-proof.

How exactly and when does this mechanism work? In our companion paper Bhattacharya and Guriev (2006) we model specifically the game between the buyer and the seller of an idea of a given quality. We show how the structure of the deal depends on the idea's characteristics. In particular, we consider two alternative modes of the sale. The first one is an "open" mode, based on patenting. In this case, the seller patents her invention and gives an exclusive license to one buyer. (Selling multiple licenses is less profitable, as the arising competition between the buyers drives down their total rents and therefore decreases the total aggregate licensing fees collected by the seller). As patenting involves describing the idea in the public domain, this mode involves partial leakage of the idea. Therefore the licensee has to compete with the other users of the idea who receive the partial value of the idea through the patenting-related disclosure. This undermines the fees that the licensee is willing to pay for the idea. Therefore the inventor may prefer the alternative, 'closed', mode.

research firms. In the Xerox case, some ideas were developed outside the XTV, and obtained financing from independent venture capitalists; some of these spin-offs were successful (Chesbrough, 2002).

The closed mode is based on trade secrets. Here, the parties do not use the patenting mechanisms – to prevent leakage to the public. On the other hand, in the absence of patents, the parties need to resolve the problem related to non-rivalry of knowledge. How can the seller commit not to sell the idea to another buyer (after the initial sale to the original buyer)? We show that the parties solve this issue using royalty-based contracts. Such contracts include a lump-sum payment and a stake in the buyer's ex post revenues.[4] If the seller receives a sufficiently high stake then the seller has an incentive to protect the buyer's monopoly power. However, there arises a moral-hazard-in-teams problem: the greater the stake given to the seller, the lower the stake kept by the buyer; and the weaker the incentives for the buyer to develop the idea into a marketable product.[5]

We show that these distortions are stronger for the less valuable ideas. This has three implications. First, the closed, trade-secret-based sale is incentive compatible only if the value of the idea is sufficiently high. Second, the closed mode (relative to the open, patent-based, mode) is jointly optimal for the buyer and the seller of the idea whenever the value of the idea is high. Third, even if the trading parties would like to choose the closed mode, their choice may be problematic given the seller's financial constraint. If the idea is very valuable, the optimal contract gives the seller a stake in the buyer's ex post revenues and a lump-sum payment. But if the idea is less valuable, the optimal contract makes the lump-sum payment to the seller negative. The seller has to pay for the royalty stake. If she has no cash, she has to find outside finance. This is where the control rights make a difference. If the seller of the idea (the inventor) and the buyer are not integrated, the inventor can find an independent Venture Capitalist to finance the deal. In case of Corporate Venturing, the vertical integration provides the inventor's employer (the potential buyer of the idea) with a right to veto outside financing.

[4]For example, a recent licensing agreement between Hoffman-La Roche (DU) and Antisoma (biotech RU) includes a lump-sum payment of $ 43 million to Antisoma, plus 10 to 20 percent royalty payments on revenues from any products developed and marketed with the licensed drug ideas. Total expected payoff to Antisoma could exceed $ 500 million, of which over 90% is based on contingent royalties, if all its licensed products are successfully launched; see Fetherstone and Renfrey (2004). Lump-sum initial payments to an exclusive licensee of intellectual property can be found in bank and hedge fund relationships, in which the latter is the originator of proprietary trading ideas, with the bank providing it investor funds.

[5]The need to give the seller a stake in ex post revenue (to prevent leaking knowledge to a competing buyer) rules out Noldeke and Schmidt's option-to-own solution.

Why would the employer want to rule out the outside financing ex ante and would he be able to commit to this veto? We show that the ex ante control by the potential buyer can strengthen the inventor's incentives to produce a more valuable idea. The intuition is that the need for outside financing arises when the value of the idea is relatively low. Even though ruling out a potential coalition with an independent Venture Capitalist is inefficient, it is the very same inefficiency that provides incentives for the inventor to reduce the probability of such low-value outcome – which, in turn, results in a higher quality of the invention.

We also show that ruling out independent financing is renegotiation-proof. Even though it is inefficient in terms of the joint surplus, this inefficiency cannot renegotiated away – exactly because of the inventor's cash constraints and the structure of the contract between the inventor and the buyer of her idea.

How does our concept of control rights over intellectual property compare to the concept of control rights over physical assets (Hart, 1996)? On one hand, these are similar – giving up control rights creates inefficiency ex post which provides more efficient incentives ex ante. Also, the ex post inefficiency is renegotiation-proof. On the other hand, our concept is very different as the key idea of alienability of physical assets does not apply in our case; our concept is based on the three specific features of the trade in intellectual property rights: non-rivalry and limited excludability of ideas and inventor's financial constraints.

Related literature. There is a large literature on the role of Venture Capital (VC) in supporting nascent, and financially constrained, innovators (see, for example, the book by Gompers and Lerner, 2004). Several authors, e.g. Kortum and Lerner (2000), have documented that VC financing enhances the performances of fledgling innovative firms–as measured by their patenting successes, or the timeliness of initial public offerings (IPOs)–differentially. In the theoretical literature on VC financing, a major focus has been on the ex ante allocation of *control rights* to VC financiers, which typically are stronger and more "invasive" than those assigned to arms-length financiers such as outside share holders, or even bank lenders. Their role in providing incentives for effort, as well as appropriate termination choices, by innovative entrepreneurs, has been examined in Berglof (1994), and Hellmann (1998), among others. Casamatta (2003) provided a rationale for the VC's dual role of financier and advisor. Kaplan and Stromberg (2003) have provided extensive documentation, as well as tests of theoretical hypotheses, regarding these contractual aspects of VC financing.

The literature on corporate venturing has focused mostly on strategic interactions be-

tween the seller and the buyer of an ideas. For example, Anand and Galetovic (2000) have analyzed the trade-off between the buyer's provision of expertise or complementary resources to the inventor, versus its subsequent ability to manipulate its reported development costs to deny the inventor's contractual share of post-development profits. Hellmann (2002) has focused more broadly, on complementarities among vs competitive impacts of final inventions on other existing products the bueyr, and how that impinges on the efficiency of development cum utilisation of the innovative ideas. An earlier synopsis of these issues and the relevant empirical evidence are provided in Gompers and Lerner (2000). Dushnitsky (2006) surveys the empirical literature on corporate venture capital. Given the obvious data issues this literature mostly focuses on the corporate venture capital, i.e. corporate funds that invest at the late stage, rather than on control over the early stage generation of ideas (which is the focus of our paper).

Our paper is organised as follows. In Section 2, we outline a simple model of generation, exchange, and development of intellectual property, which generalizes the setup in our companion paper, Bhattacharya and Guriev (2006). The companion paper characterizes the equilibrium at the ex interim stage holding constant the ex ante investment by inventor. The companion paper also assumes away financial constraints. In Section 3 we establish our main result on corporate venturing, constructing a parametric numerical example to establish the feasibility of renegotiation-proof control rights prohibiting third party external financing. Section 4 concludes.

2 The model

2.1 The setup

The setting is a generalization of the model in Bhattacharya and Guriev (2006). There are three risk-neutral agents. There is an inventor who creates an idea and sells it; to make the notation consistent with Bhattacharya and Guriev (2006), we will call this agent a 'research unit', RU. There are also two competing buyers of the idea; these buyers can develop the idea into a marketable product. We will refer to them as 'development units' DU_1 and DU_2. The investments in research and development are sequential. First, RU produces knowledge $K \in [0,1]$. This knowledge is an input in the development stage which may result in the

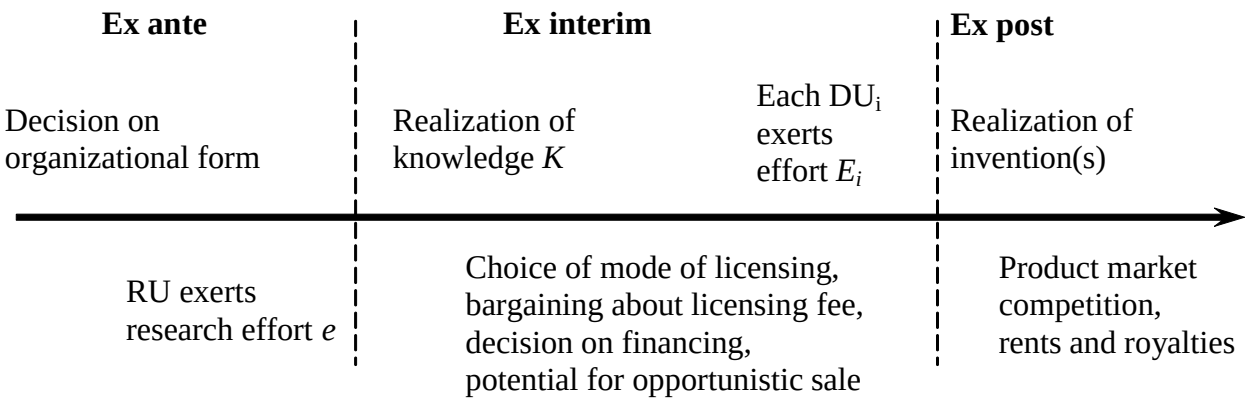

Figure 1: Timing.

creation of a new product. If only one DU develops successfully, he obtains a monopoly rent of $V = 1$ in the product market. If both DUs succeed in development, they compete a la Bertrand and each gets zero rent. Both DUs have deep pockets, while RU is financially constrained; it needs external financing ex ante, or ex interim.

The timing is presented in Figure 1. The model in Bhattacharya and Guriev (2006) solves for the equilibrium mode of knowledge sale and licensing fees for a given quality of the idea K (i.e. the outcome of ex ante stage is exogenous). In this paper, we endogenize the choice of the ex ante research effort that affects the quality of the idea K and show how organizational form (independent vs. Corporate Venturing) affects incentives for ex ante research.

We assume K to be the outcome of a random process with a distribution $G(K; e)$ that depends positively on RU's costly effort choice, e, ex ante. Subsequently, each DU exerts development its effort E which leads to the successful development with probability P. The cost of effort is a function of both the induced probability of success P DU wants to achieve and the available knowledge K: $E = C(P, K)$. increasing in P and decreasing in K. We assume that $C(P, K)$ is a neoclassical constant-returns-to-scale function,

$$E = C(P, K) = Kc(P/K)$$

where function $c(\cdot)$ is an increasing and convex function: $c' > 0$, $c'' > 0$. We will also make a technical assumption that $c'''(\cdot)$ has a constant sign.

Without loss of generality we normalize K so that $c'(1) = 1$. In this case, knowledge level K is metrized in terms of the maximum probability of successful second-stage invention it

may lead to (if there were no distortions, $P = \arg\max_P [P - C(P, K)] = K$). In all equilibria considered in the paper $P \leq K$. While all the results below hold for this general neoclassical cost function, for the sake of simplicity we will focus on the Cobb-Douglas parametrization $c(P/K) = \alpha(P/K)^{1/\alpha}$, where $\alpha \in (0, 1)$.

Both efforts e and E are measured in terms of their costs, which are assumed to be non-verifiable. The realized knowledge level K is assumed to be communicable by an RU to its licensee DU, but is non-verifable by Courts. We now describe the processes of choice over modes of knowledge licensing, and of bargaining on the division of surplus, which serve to endogenize effort choices.

2.2 Timing and assumptions

The timing of events is as follows. Ex ante, the parties choose an allocation of control rights: either (i) RU and DUs are independent, or (ii) one DU has control over RU. Then RU invests e in(stochastic) interim knowledge generation.

Ex interim, knowledge K is realized. The parties choose the mode of licensing of RU's knowledge, and bargain over the licensing fee. The bargaining game in each mode, with and without patenting, is sketched below; see Bhattacharya and Guriev (2006) for a fuller description. There are two alternative modes of knowledge licensing. One is the *open*, or patent-based mode, and the other one is *closed*, or trade-secret-based mode. In the open mode, a patent on K is registered, so that RU can commit to sell her knowledge to one buyer only. RU describes her knowledge publicly which leads to a partial leakage thereof;[6] an exogenous proportion $L \in [0, 1)$ of the capability K is transferred to both DUs. Both DUs also infer the *level* of RU's knowledge K from this patent description. RU then invites competing bids–sequentially, via rounds of offers and counteroffers potentially alternating across the two DUs. The buyer i that licenses the full *content* of RU's knowledge pays RU a lump-sum licensing fee F_o, and chooses its probability of successful development P_i which in turn implies the effort choice E_i. The other potential buyer j does nto receive the full knowledge. He only has access to the leaked description LK. He chooses the effort E_j. These effort choices $\{E_i, E_j\}$ or, equivalently, choices of probabilities of success $\{P_i, P_j\}$)

[6] Empirically, leakage effects of patenting are well-documented, and result in many inventions not being patented; see Cohen, Nelson, and Walsh (2000), for example.

constitute Nash equilibrium strategies in the post-licensing subgame between these two DUs. The efforts and probabilities are related as follows: $E_i = C(P_i, K)$ and $E_j = C(P_j, LK)$.

In the *closed* trade-secret based mode, knowledge licensing occurs through a private sale of the contents of K to one of the DUs. If RU is indepenpendent, the buyer is randomly chosen by an independent RU. In the Corporate Venturing scenario, the buyer is the DU_i that has control rights over RU. The parties bargain bilaterally about their licensing contract. Their payoffs are contingent in part on DU_i's post-invention revenues. This serves the role of eliminating RU's temptation to make a clandestine second sale of the knowledge K to the competing DU_j. As the ex post outcome is binary ($V = 1$ or $V = 0$), this licensing contract includes only two variables: an interim lump-sum transfer F_c (which may be positive or negative) and RU's royalty share s in DU_i's ex post revenues. To initiate the bargaining, RU provides a description of her knowledge, which is sufficient for DU_i to infer its level K. This description leads to some partial leakage of RU's knowledge, LK, to DU_i.[7] After RU and DU_i agree on these terms of licensing, RU reveals the full content of her knowledge to the licensee DU_i. The buyer DU_i then chooses his development effort E_i. We denote as P_c his resulting choice of the probability of final invention.

As we show in Bhattacharya and Guriev (2006), the contract between RU and DU_j is structure so that RU does not sell her knowledge to the competing buyer DU_j in equilibrium? In this opportunistic deviation by RU, she would first describe her knowledge to DU_j; this would cause leakage LK. If they agreed on a fee for RU disclosing the full content of her knowledge, DU_j would then choose the probability of development P_d (where d stands for 'deviation') given DU_i's choice of P_c. If RU and DU_j fail to agree upon the licensing fee, DU_j would develop on the basis of leaked knowledge LK; in this case we denote his choice of probability of invention as Q_d. By choosing RU's revenue share s appropriately, DU_i will try to prevent the RU disclosing her knowledge K to DU_j. If s is sufficiently high, RU would rather protect DU_i's ex post rents from competition, after taking into account the maximum that DU_j would pay.

[7] We assume the same degree of leakage in open and closed modes. While such an assumption is not unrealistic, it is not essential for our results; see Bhattacharya and Guriev (2006) for the analysis of a more general setup. Note also that it is always feasible for an RU to patent her knowledge, contingent on any disagreement with her potential licensee DU

2.3 Interim payoffs

We will denote as $U_{oi}(P_i, P_j; K)$ the expected ex interim payoff of the licensee DU_i in the development race in the open mode, whereas the other DU_j chooses probability of invention P_j to maximize $U_{oj}(P_j, P_i; LK)$. These payoffs are

$$U_{oi} = [(1-P_j)P_i - C(P_i, K) - F_o] \quad (1)$$

$$U_{oj} = [(1-P_i)P_j - C(P_j, LK)] \quad (2)$$

The RU receives F_o.

Correspondingly, in the closed model of knowledge sale the licensee DU obtains:

$$U_c = [(1-s)P_i - C(P_i, K) - F_c] \quad (3)$$

where P_c is the optimal choice of P_i in this mode. The RU's payoff consists of the royalty sP_c and the cash payment F_c made before the choice of development effort. The non-licensee DU_j receives nothing in equilibrium. The licensing terms, F_c and s, are chosen via bilateral bargaining between RU and DU_i; We shall assume equal bargaining powers, based on alternating offers a la Rubinstein (1982), for the RU and her chosen licensee DU.

2.4 The mode of licensing and the structure of licensing fees

Let us first assume that RU's financial constraint is not binding. Then the choice of the mode maximizes the total (subgame-perfect) equilibrium payoffs summed across the RU and her licensee DU. We will denote as T_c and T_o the joint ex interim surplus of the RU and her licensee DU_i in the closed and in the open mode, respectively.

Open mode. If a patent is registered then the licensee DU_i pays RU a licensing fee F_o and obtains knowledge K. At the same time, knowledge LK is leaked to the public domain, so the competing DU_j can also engage in the development contest. The joint surplus of RU and DU_i will therefore equal $T_o = [U_{oi} + F_o]$; see (1). The competing DU_j will use the leaked knowledge LK, and will therefore receive $[(1-P_o)Q_o - C(Q_o, LK))]$. Here the probabilities $\{P_o, Q_o\}$ satisfy the Nash equilibrium conditions:

$$\begin{aligned} c'(P_o/K) &= 1 - Q_o, \\ c'(Q_o/LK) &= 1 - P_o. \end{aligned} \quad (4)$$

Under the assumptions above, for each pair of K and L the solution exists, and is unique. Both T_o and P_o increase with K, P_o decreases with L, Q_o increases in L. Fo is in(de)creasing in K (L).

Essentially, the sequential offers bargaining process in this mode results in Bertrand competition between the two DUs: RU extracts all the additional surplus of the licensee DU_i, making his participation constraint bind. The equilibrium payoffs of the RU and DU, characterised in Bhattacharya and Guriev (2006), are as follows:

$$T_o = K[(1-Q_o)P_o/K - c(P_o/K)]; \quad U_o = T_o - F_o = LK[(1-P_o)Q_o/(LK) - c(P_o/(LK))]. \quad (5)$$

where P_o, Q_o solve (4).

Closed mode. If the contracting parties do not register a patent but choose disclosure via a closed sale, there is no leakage to outsiders in equilibrium. However, in order to provide RU with incentives not to disseminate knowledge to the competing DU_j, DU_i has to give away a sufficient share s of his ex post revenues in royalties to RU, so that:

$$[sP_c - sP_c(1-P_d)] \geq [\{(1-P_c)P_d - C(P_d, K)\} - \{(1-P_c)Q_d - C(Q_d, LK)\}] \quad (6)$$

where P_c is chosen by the licensee DU_i and $\{P_d, Q_d\}$ are the potential choices of the other DU_j if the RU attempts to sell knowledge to her. P_d is chosen by DU_j if she has full knowledge, and Q_d is her choice with leaked knowledge LK. For a given share s, the left-hand side in (6) is the reduction in the RU's expected royalty payoff due to opportunistic disclosure to DU_j. The right hand side is the maximum licensing fee that RU may extract from DU_j, in case she decides to disclose to him after licensing her knowledge to DU_i. The logic of calculating this licensing fee is very similar to the one in patent-based licensing: since the process of negotiating the clandestine knowledge sale results in a partial leakage of knowledge LK, RU would obtain from DU_j at most the expression in the right-hand side. If and only if (6) is violated, there exists a fee that DU_j will be willing to pay and RU will be willing to accept in exchange for the clandestine second sale of her idea.

While giving a sufficiently high share of ex post revenues to RU rules out opportunistic disclosure, it comes at a cost of lowering the licensed DU's incentives to apply effort. Indeed,

by solving for optimal effort of DU_j and DU_i we find that P_c decreases in s :

$$c'(P_d/K) = 1 - P_c \tag{7}$$

$$c'(Q_d/(LK)) = 1 - P_c \tag{8}$$

$$c'(P_c/K) = 1 - s \tag{9}$$

In equilibrium, RU and DU_i will choose the minimum possible $s \in [0,1]$ that satisfies the incentive constraint (6). Therefore this constraint should be binding. For the Cobb-Douglas function, we substitute (7)-(9) into (6) and find

$$s = (1-\alpha)(1-L)\left(\frac{1}{K}(1-s)^{-\frac{\alpha}{1-\alpha}} - 1\right). \tag{10}$$

Lemma 1 *Assume a Cobb-Douglas technology $c(P/K) = \alpha(P/K)^{1/\alpha}$. A mechanism for a closed knowledge sale, which is incentive-compatible for no further disclosure by the RU, requires RU to be given a (minimum) share $s = s^*(K;L)$ in her licensee DU's post-invention revenues, where $s^*(K,L)$ solves (10). This closed mode licensing is only feasible if such $s^*(K;L)$ exists. The licensee DU develops with probability $P_i = P_c = K(1-s^*(K;L))^{\frac{\alpha}{1-\alpha}}$, the other DU does not develop. The joint payoff of RU and the licensee DU is*

$$T_c = P_c - C(P_c, K) = K\left[(1-s^*(K;L))^{\frac{\alpha}{1-\alpha}} - \alpha(1-s^*(K;L))^{\frac{1}{1-\alpha}}\right]. \tag{11}$$

The following comparative statics holds:

1. *Closed mode licensing is feasible whenever K and L are sufficiently large.*
2. *The incentive-compatible revenue share s decreases in K and in L.*
3. *The joint payoff T_c of RU and the licensee DU increases in K and L.*
4. *The value of RU's royalty share sP_c* decreases *in K.*
5. *The lump-sum fee $F_c = T_c - sP_c$ increases in K.*

3 Control rights and ex ante incentives

The solutions above neglect the RU's ex interim financial constraint. This constraint is binding whenever the level of RU's required revenue share s to ensure an exclusive closed-mode sale is so high that RU has to make a lump-sum payment to her licensee DU_i to

persuade her to choose the closed mode ($F_c < 0$). This is the case when knowledge K is sufficiently low while the minimum incentive compatible equity stake sP_c is high.

Such a binding financial constraint may result in ex interim inefficiency in licensing. There may arise a situation where the joint surplus is higher in the closed mode, $T_c > T_o$, but the licensee DU_i prefers the open mode. This disagreement occurs whenever $(T_o - F_o) > (T_c - sP_c)$. If RU had deep pockets, she would pay DU_i a lump-sum amount $-F_c$ at the interim stage for forgoing the open mode option. But since RU is cash-constrained the ex interim efficient mode can only be implemented if she has some external source of financing.

We will now consider two scenarios of control rights. First, we consider a situation where the parties ex ante agree on the RU remaining independent. In this case the RU may overcome this ex interim inefficiency using outside venture capital finance. The second scenario is that of corporate venturing, whereby RU may commit ex ante to remain financially constrained ex interim, through giving control rights ruling out such third-party financing ex interim to DU_i. This commitment implies ex interim inefficiency; but since this inefficiency is more likely to arise for lower K, RU would have stronger incentives to exert effort ex ante to increase K and avoid such outcomes.

Independent inventor. If RU is independent and requires external financing ex interim, she may join forces with a venture capitalist (VC) who will provide cash to pay the licensee DU_i the amount $I = [(T_o - F_o) - (T_c - sP_c)]$ ex interim, in exchange of I/P_c shares out of the s share of DU_i's revenue. It is crucial that such a VC is able to ensure that RU acts in the interest of their RU-VC coalition. Therefore RU does not disseminate knowledge to DU_j even though she only has a stake of $s - I/P_c$ in DU_i revenues. We believe that this is a reasonable assumption: VC is not a regular financial intermediary, but a specialized entity with reputational concerns, which can prevent opportunistic behavior by its coalition partner.

Corporate venturing. The second scenario is corporate venturing. Ex ante, RU and DU_i agree that RU will cede control rights to DU_i. We do not assume alienability of RU's intellectual capital. The allocation of control rights implies only that RU's outside financing can be vetoed by DU_i. Also, RU is required to start negotiations with DU_i first and is not

allowed to sell her knowledge to a competing DU_j exclusively.[8] It is easy to see that under corporate venturing, DU_i could commit to veto a RU-VC alliance. One way to commit to this veto would be to sign a contract ex ante, stating that if RU signs any share contracts with outsiders, her partner VC must pay DU_i a sufficiently high penalty for a breach of her ex ante agreement with DU_i.

We assume further that an RU cannot make a binding promise to her controlling DU_i about any prospective ex interim payment, if the DU were to rescind her veto power on third-party financing. We then show, via a numerical example, that our notion of DU's control rights is renegotiation-proof: ex interim, DU has no incentive to relax her control rights and allow independent financing of RU.

As corporate venturing rules out relaxing RU's financial constraint, it may result in knowledge licensing via the open mode when the closed mode is ex interim efficient (in terms of the joint surplus of RU and DU_i). Why would parties want to sign such a contract? The reason is that although the independent RU scenario is efficient ex interim, it may provide RU with inadequate incentives ex ante. As shown above, unlike F_o or T_c the value of RU's revenue share sP_c is *decreasing* in K. Therefore the RU's financial constraint $F_c \geq 0$ tends to bind at low levels of K. By forcing open mode sales via corporate venturing for such knowledge levels, a controlling DU_i may indeed create ex interim inefficiencies. However, he may also enhance RU's ex ante incentives to invest in research leading (stochastically) to higher levels of K.

Whether corporate venturing is efficient ex ante depends on the relative strength of these ex ante and ex interim effects. Below we illustrate this tradeoff, in the context of a simple set up in which where RU can choose one of two effort levels: high or low. The high level of effort costs her e dollars more, but also produces higher knowledge $K = K^H$ ex interim with probability 1. The low effort produces only $K = K^L$ with probability 1, where $K^L < K^H$. Suppose that in both states the closed licensing mode dominates the open mode:$T_c^k > T_o^k$, $k = L, H$. Let us also assume that in the high state RU's financial constraint is not binding, while in the low state it does bind $s^L P_c^L > \max\{T_c^L/2, T_c^L - T_o^L + F_o^L\}$. The latter implies that the RU's financial constraint is binding in the low state, in so far as the DU_i would prefer open-mode licensing in the absence of a transfer $F_c < 0$ to him. Then corporate

[8] In the closed mode the disclosure of knowledge to DU_j, or any cash transfers resulting from it, cannot be tracked, but any revenue sharing contract between RU and a third party is by definition verifiable.

venturing matters in the low state, and will affect the RU's payoff if a lower level of effort is chosen ex ante.

Proposition 1 *Corporate venturing will strictly increase RU's research effort if*

$$\max\{T_c^H/2, F_o^H\} - e < s^L P_c^L - I^L \text{ and} \tag{12}$$

$$\max\{T_c^H/2, F_o^H\} - e > F_o^L. \tag{13}$$

Corporate venturing will be adopted ex ante if the change in research effort is cost-efficient:

$$(T_c^H - e) - T_c^L > 0. \tag{14}$$

Since the closed mode is more efficient in the low state, $s^L P_c^L - I^L = F_o^L + T_c^L - T_o^L > F_o^L$, the conditions (13) are consistent for a range of effort costs e.

To illustrate further the importance of this Proposition, we consider the following numerical example. For the sake of simplicity we specialize, use a quadratic cost function $C(P, K) = P^2/(2K)$. Table 1 describes below the parameter values for which the conditions above are satisfied. We consider the case with $L = 0.8$, $K^L = 1/3$, and $K^H = 1/2$. Indeed, the conditions (12)-(14) imply $e > 0.123 - 0.069 = 0.054$, $e < 0.123 - 0.037 = 0.086$, and $e < 0.246 - 0.14 = 0.106$. Hence, for all $e \in (0.054, 0.086)$ corporate venturing strictly increases ex ante welfare and will therefore be a candidate equilibrium outcome.

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Let us examine the issue of ex interim renegotiation-proofness of the restriction on third party financing in the low state. Notice that in this example, for $K = K^L$, DU's payoff in the open mode $U_o = T_o - F_o = 0.071$ binds as an outside option relative to her symmetric share of the surplus in the close mode $T_c/2 = 0.070$. Thus, DU would not expect to be made an offer of a payoff greater than 0.071 if she were to allow the RU to form a coalition with VC ex interim. Hence, her *enforcement of the control right* that precludes RU from forming a financial coalition with a third party VC would remain *renegotiation-proof* ex interim, as well as being beneficial ex ante for a large range of effort costs e.

In this example, once the high effort level is chosen ex ante, corporate venturing actually becomes irrelevant ex interim (financial constraint is not binding in the high state); hence corporate venturing does not even result in ex interim inefficiency. The latter is an artifact

	$K = K^L$	$K = K^H$
K	0.33	0.5
L	0.8	0.8
T_o	0.108	0.141
T_c	0.140	0.246
F_o	0.037	0.063
$T_o - F_o$	0.071	0.078
$T_c/2$	0.070	0.123
s	0.4	0.130
P_c	0.2	0.431
sP_c	0.08	0.056
$T_c - sP_c$	0.06	0.189
I	0.011	–
$sP_c - I$	0.069	–

Table 1: A numerical example where corporate venturing is ex ante efficient.

of our assumption that the high effort level rules out the $K = K^L$ state with probability 1. If the low knowledge state occurred under high effort with a non-trivial probability, the results in Proposition 1 could be easily generalized; but corporate venturing would now create an ex interim inefficiency in the licensing process.[9] Indeed, thereby corporate ventured RUs may patent more often, than independently financed (ventured) researchers.

4 Concluding remarks

In this paper, we have elucidated a theory of control rights in the context of licensing interim innovative knowledge for further development, which is consistent with the inalienability of initial innovator's intellectual property rights. Control rights of a downstream development unit (a buyer of the interim innovation), arises from his ability to prevent his affiliated upstream research unit (the innovation's seller) from forming financial coalitions at the ex interim stage with independent financiers. By constraining the flexibility of the research unit

[9] As we show in our companion paper, such "inefficiency" need not be socially suboptimal, once one takes into account the non-licensee DU.

in this manner, the controlling development unit is able to reduce the research unit's payoffs, in contingencies where the latter generates lower levels of interim knowledge. This provides the research unit with greater incentives to expend costly effort ex ante, helping to generate more productive interim innovations.[10]

Unlike in the earlier paper of Aghion and Tirole (1994), which deals (ostensibly) with bargaining and control rights in a context of sequential and cumulative innovative activities, we do not assume that the control right of the innovation's buyer over its seller implies full alienability of the intellectual property (IP).[11] In our setup, an upstream RU always retains the right to patent her IP and invite competing bids for its licensing from all DUs, as well as that of bargaining with her controlling DU about the terms of trade-secret based licensing. Our corporate venturing DU obtains only the control rights of (a) first offer, cum knowledge description, for a trade secret based license, and (ii) vetoing potential formation of financial coalitions, involving contingent sharing contracts, with third parties by the controlled RU. This second right is also necessary for the controlling DU, in order to effectively implement the first one.

In more recent work on incomplete contracts and control, Hart and Moore (2004) have also advanced a notion of control rights that is distinct from that of residual rights to control, or ownership, over physical or intellectual (as in Aghion and Tirole 1994) property. Their formulation pertains to ex ante contracts ruling out future (ex interim) renegotiations over a subset of (verifiable) items therein, in the interest of enhancing ex ante incentives for allocation of efforts. Our construction, of control rights in the form of ruling out future financial coalition formation with third parties by the controlled agent, shares a family resemblance with theirs. However, we go further; as we showed in section 3, for at least a connected subset of parameters, our control right remains renegotiation-proof ex interim, provided that the controlling party is also the downstream knowledge licensee, a corporate venturer, rather than an independent third-party (VC) financier cum partner.

The empirical implications of our results are as follows. Controlling for quality of research, industry and size, internal corporate venturing should result in a greater prevalence

[10] This is not feasible with ex ante revenue sharing on the interim knowledge K, owing to non-verifiabilty of realized K in courts; see below.

[11] The researchers often manage to appropriate a substantial share of the surplus. Recently, a Japanese court enhanced the reward of an inventor, holding a patent jointly with his ex-employer, from 20,000 to 20 billion yen (189 million dollars); see New York Times (2004).

of patenting rather than closed-mode sales – relative to R&D financed by independent venture capital. We would also expect to see greater prevalence of corporate venturing in R&D sectors in which patenting is not viewed as the preferred mode of protecting intellectual property rights, owing to high leakage of non-codifiable aspects of interim innovative ideas. These are the sectors in which not only would forcing RUs to patent lower-quality ideas, via denial of access to third party external financing, be credible ex interim for controlling DUs, but also beneficial in terms of enhancing RUs' ex ante incentives to produce higher quality innovations. However, empirical verification of this prediction would be fraught with many difficulties. Such an impact of corporate venturing would not be captured by a higher degree of patenting activity by corporate VC sponsored firms within a sector, as that could result from the failure of resulting ex ante incentives! Indeed, RUs sponsored by independent VCs might patent more, if for some lower quality ideas it is more efficient to patent, if the resulting level of knowledge leakage is only moderate.

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