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CONTROL RIGHTS OVER INTELLECTUAL PROPERTY*

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We consider an incomplete contracting model of bilateral trade in intellectual property (IP) with sequential investments in its quality and with financial constraints. A financially-constrained inventor invests in an idea which she then sells to a buyer. The buyer in turn invests in developing this idea into a marketable product. We propose a novel formulation of *ex ante* control rights of an IP buyer, over the financially-constrained IP seller. We do not assume alienability of the inventor's ideas; the control right is defined as *ex ante* prescribed prohibition of *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 potential partners of the seller, such as independent venture capitalists. We thereby obtain a rationale for a key role of Corporate Venturing in promoting innovative activities.

I. INTRODUCTION

IN THIS PAPER WE DEVELOP A NOVEL CONCEPT of control rights in research and development. We consider the case of sequential innovation where inventors/researchers generate knowledge (or ideas) and sell it to large firms that, in turn, develop these ideas into marketable product. Usually, the inventors that generate ideas are financially constrained. They have two choices of raising funds for their work. First, they can be funded by venture capital firms that are independent from the buyers of the ideas. The venture capitalists are professional financial intermediaries; while they do have sectoral expertise, they do not buy or sell ideas *per se*—their business is to

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fund the generation of ideas and then receive financial returns. For example, the most renowned venture capital firms such as Kleiner, Perkins, Caufield and Byers and Sequoia Capital invested during early stages in Amazon, Apple, Cisco, Compaq, Google, Netscape, PayPal, Sun, YouTube (as well as many other successful digital companies) and profited through selling their stakes at later stages.

There is however an alternative way of funding early stage innovation, so called Corporate Venturing. Unlike the situation with funding of inventors by independent venture capital (VC), in the case of corporate venturing (CV) inventors work within a corporation that tries to emulate the venture capital marketplace in house. The corporation is both the buyer/user of the knowledge and the provider of financing. The classical case of such corporate venturing is Xerox Technology Ventures (see Hunt and Lerner [1995], and Chesbrough [2002]).[1] In 1988, Xerox Chairman David Kearns committed $30 million for investment in promising technologies developed within Xerox; and in the next eight years, Xerox Technology Ventures had interest 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 had committed to, the financial returns exceeded those of comparable independent venture capitalists.

Development of ideas both outside and within the downstream firms is common in practice. In fact, the same companies may use both approaches at the same time. For example, the large pharmaceutical companies now receive a substantial part of revenue (about half, Wood Mackenzie [2004]) from the development of drug ideas that were outsourced, or licensed from external 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]).

This brings us to the main question of our paper: Why do some parties use the corporate venturing arrangements while the others stay independent? This is a relevant challenge for both inventors who start off as independent or and for inventors who generate ideas while being corporate employees. The independent inventors can choose to remain independent

[1] While having become a canonical example of a corporate venture fund, the Xerox Technology Ventures was not the first or the largest among those. The first corporate venture funds started in 1960's; according to the history of corporate venture in Gompers and Lerner [2004], in the late 1960's and early 1970's 'more than 25 per cent of the *Fortune 500* firms attempted corporate venture programs.' The interest in corporate venturing reemerged again in mid-80's and then again in mid-90's when corporate venture funds constituted about 12 per cent of the total venture capital pool. In April, 2013, the *Global Corporate Venturing* magazine reported that it was tracking about 400 corporate venture units in the U.S. and about 600 outside the U.S.

(and use VC financing) or to sell their firm to a large corporation that wants to make use of their ideas. The latter format will result in vertical integration and corporate venturing. Alternatively, the employees of a corporation may choose whether to preserve the status quo and innovate within the corporation or to create a spin-off by becoming independent inventors. In order to understand these choices, we analyze incentives in the vertical relationship between the inventor and the developer.

We develop a model of trade in ideas where the seller of an idea (the inventor) can invest in its quality, while the buyer of the idea can invest in its further development and marketability. We then distinguish Corporate Venturing as the approach in which there is a vertical relationship between the buyer and the seller of the idea. We explicitly model the control rights that follow from this vertical relationship and provision of funding by the buyer.

Our model has three specific features that are characteristic of trading in ideas (following the seminal paper by Anton and Yao [1994]). First, ideas are non-rival. Even after an idea is sold to one buyer by the inventor, the seller continues to keep the technological (although not necessarily legal) opportunity to sell the idea again to an alternative buyer. This is very different from physical assets—if one party uses the 100% of the asset, the other party cannot use it at all. This non-rivalry does not mean that appropriate property rights for the idea (or the incentives not to resell the idea) cannot be set up. We discuss in the paper the mechanisms that the trading parties use—patents, trade secrets, contingent royalties—in order to prevent (partially or fully) the 'second sale' of the idea. Yet, the threat of such a second sale is a crucial distinction of trading ideas relative to trading physical goods—if a piece of equipment is bought and used by one customer, it cannot be used by another customer.

Second, there is only a limited excludability; it is hard for the inventor to prevent the leakage of her idea to others. Already by describing the idea to a potential buyer, the inventor gives away a certain share of the idea's value. This is again different from physical goods and assets: in case of a physical good, the buyer can only use it after it is physically transferred to the new owner/user. We assume that there is a patent system that may partially address the leakage. Yet, obtaining a patent also provides a description of the idea in the public domain—thereby undermining the seller's licensing fee for divulging is full content. We will assume that patents work in the sense that they rule out free imitation of ideas. However, we will also allow for leakage (trivial, partial, or full)—because of the limited excludability. Again, this is an important difference from the trade in physical goods. If a piece of equipment is used by its owner, she can rule out the use of the very same equipment by her competitor. In the case of an idea/invention/know-how it is very hard to prevent the leakage of value to the competitor.

The third key ingredient, which allows us to introduce the value of corporate venturing, is the inventor's financial constraint. Most inventors lack funds to develop their ideas into marketable products. This imposes constraints on the design of the structure of knowledge exchange and contractual mechanisms.

In this setting, corporate venturing can help to provide stronger incentives to the inventor (that are otherwise weakened by the non-rivalry and non-excludability of intellectual property). Unlike Aghion and Tirole [1994], we do not assume that vertical integration provides the buyer of the idea with control over the inventor's human capital. In their paper, vertical integration allows the buyer (employer) to force the seller (employee) to sell her idea on the terms the employer prefers. Aghion and Tirole assume that the parties can directly allocate property rights over inventions (in the conventional understanding of property rights as defined for physical assets). This is equivalent to assuming alienability of the inventor's human capital. In such a setting, the buyer of the idea can solve—at no cost—the problems of non-rivalry and non-excludability. Integration implies the buyer's ability to rule out 'second sale' of the idea by its inventor to the buyer's competitor and to limit the leakage of knowledge to competitors.

We use a much weaker—and, as we believe, much more realistic—concept of vertical integration and of control rights. We allow for the possibility of an inventor's being able to sell her idea secretly to an alternative buyer and for leakage of knowledge. Our definition of control rights is different from that of Aghion and Tirole who allow forcing the inventor to sell the idea to the vertically integrated buyer without any leakage to other potential buyers. 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 of ideas, and therefore the split of the surplus—generating a greater share of the surplus for inventors with more valuable ideas.

By accepting this form of vertical integration (Corporate Venturing), the inventor agrees *ex ante* to constraining her choice of the structure of the *ex post* sale of her ideas. This certainly reduces her payoff in some circumstances and may therefore influence for her *ex ante* incentives to invent. In particular, the inventor invests effort in projects that are less likely to end up in such outcomes. Such a reallocation of control rights creates a trade-off between *ex ante* inefficiencies in incentivizing innovative effort, and *ex post* inefficiencies in surplus maximization; the latter arise whenever outside financing would help enhance the joint surplus. We show that when control rights over external financing are shifted to the buyer of the idea, the *ex post* surplus is reduced but the inventor's incentives to invest in higher-payoff ideas may be strengthened; therefore Corporate Venturing can be preferred in equilibrium. Also, because of reasons pertaining to the inventor's

financial constraint, control rights in Corporate Venturing may remain 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 over licensing of an idea of a given quality. We show how the structure of the transaction depends on the idea's characteristics.[2] 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. As patenting involves describing the idea in the public domain, this mode involves a partial leakage of the idea. Therefore the licensee has to compete with other users of the idea who partially appropriate some aspects 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.

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 incentive issues related to the non-rivalrous nature 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 may resolve this issue by using royalty-based contracts, which consist of a lump-sum payment and a stake in the buyer's *ex post* revenues arising from invention(s) based on the idea.[3] If the seller receives a sufficiently high stake then the seller has an incentive to protect the buyer's monopoly power.[4] However, there arises a moral-

[2] In Bhattacharya and Guriev [2006], we assume away financial constraints and therefore do not analyze control rights. The other distinction from Bhattacharya and Guriev [2006] is that in this paper we allow for quality of knowledge to depend on the inventor's endogenous effort. Finally, in this paper we consider more general functional forms.

[3] The endogenous choice between licensing based on patents vs. trade secrets distinguishes our paper from Anton and Yao [1994]. In their canonical model, leakage of the content (hence value) of any innovative idea arising from its description, in any domain, is full, so that no analog of a patent-based licensing mechanism, with strictly positive licensing revenue for the idea seller, can exist. However, sale based on a private description of an idea is still feasible, at some strictly positive price as they show, because the seller can use the threat of divulging her idea to another (competing) buyer, to reduce the disagreement payoff to her potential buyer. However, on reaching agreement on such an exclusive sale, the seller has no further ability to extract a strictly positive price in a clandestine second sale, unlike in our setup where leakage is only partial.

[4] The royalty stakes are often very high. For example, a licensing agreement between Hoffman-LaRoche and Antisoma (a biotech firm) included a lump-sum payment of $43 million to Antisoma, plus 10 to 20 per cent 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 Featherstone 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's providing it investor funds.

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 successful final 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 our control rights make a difference. If the seller of the idea (the inventor) and the buyer are not integrated, the inventor could possibly find an independent Venture Capitalist to finance the deal. In case of Corporate Venturing, the vertical integration provides the inventor's employer, and potential buyer of the idea, with a right to veto such outside financing.

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 more valuable ideas. 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 can be inefficient *ex interim*, it is the very same inefficiency that encourages the inventor to reduce the probability of such low-value outcomes—and, in turn, provides her with incentives for higher quality inventions.

We also show that ruling out independent financing can be renegotiation-proof. Even though it is inefficient in terms of the joint surplus obtained by the buyer and the seller, such inefficiency need not be renegotiated away—owing to the inventor's cash constraint. This is the case when the inventor, together with a potential independent VC partner, can not credibly pre-commit to provide the buyer with a payoff strictly higher than what he would obtain in the patent-based mode, in their subsequent bargaining in closed mode.

How does our concept of control rights over intellectual property compare to the concept of control rights over physical assets? On the one hand, these are similar—giving up control rights creates inefficiency *ex post*

[5] The need to give the seller a stake in *ex post* revenue (to prevent leaking knowledge to a competing buyer) rules out standard incomplete contract theory solutions (e.g., the options-to-own in Noeldeke and Schmidt [1998]).

which provides more efficient incentives *ex ante*. Here, 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 inventors' financial constraints.

The rest of the paper is organized as follows. In Section II, we discuss related literature. In Section III, 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]. In Section IV, we establish our main result on corporate venturing, establishing the feasibility of renegotiation-proof control rights prohibiting third party external financing. In Section V, we discuss robustness of our results. Section VI discusses empirical implications of our theory. Section VII concludes.

II. 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 (IPO's)—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 between the seller and the buyer of an idea. 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] considers the incentives of the downstream partners to develop and market final inventions that are substitutes vs. complements to their existing products. This theme is further developed in Hellmann [2007] where the inventor's firm may be afraid of providing strong incentives for

internal ventures as the latter may result in too much exploration of new ideas at the cost of inefficient exploitation of the firm's core business. While Hellmann [2007] does study the choice to invest in invention and development of the idea by the firm, our analysis is different as we endogenize the inventor's potential interactions with other potential buyers of the intellectual property, and with independent venture capitalists.

An earlier synopsis of these issues and the relevant empirical evidence is provided in Gompers and Lerner [2000]. Dushnitsky [2006] surveys the empirical literature on corporate venture capital.[6] Given the obvious data issues this literature mostly focuses on the corporate venture capital, i.e., corporate funds that invest at a late stage, rather than on control over the early stage generation of ideas (which is the focus of our paper).

Our theory is somewhat similar to that of vertical integration in the incomplete contract theory. The latter (Hart [1995]) considers situations where the trading parties can make relationship-specific investments in human capital that are 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 reduce the value of the original counterpart's specific investment (which is complementary to the asset). Thereby property rights over the asset provide the owner with a stronger *ex post* bargaining position, and therefore a better command over the distribution of the *ex post* surplus.[7] The conventional incomplete contract analysis does not apply however to the case of intellectual property as it is not a physical asset, and human capital is not alienable. This is why, in order to understand vertical relationships in the trade of ideas (corporate venturing), we need to develop a new theory of control rights over intellectual property.

Our notion of control rights is related to the mechanism of non-compete agreements (labor contract clauses that limit mobility of inventors to competing employers). The enforcement of non-compete agreements allows an inventor to commit to a labor relationship with a firm. As is shown in Marx *et al*. [2009], non-compete agreements do have a substantial impact on the

[6] 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. Such arm-length corporate venture capital is equivalent to independent venture capital in our model. 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.

[7] Allocation of ownership works especially well if the parties invest sequentially. Noeldeke 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 choices as in Hart [1995], where the potential buyer has control over the seller via owning physical assets.

mobility of inventors; the effect is especially strong for the most productive inventors. Belenzon and Schankerman [2013] also show that non-compete laws matter have an effect of knowledge dissemination. They study geographical knowledge spillovers emanating from universities (using data on citation of both patents and scientific publications) and show there are state border effects which are especially large for states with non-compete laws. We show that these laws also strongly affect the extent of (localised) knowledge spillovers emanating from universities (presumably working through labor mobility).

In our model, financial contracting with a third party (and independent venture capitalist) is similar to employment at a competing firm. Both are observable and therefore can be ruled out by an *ex ante* contract (either corporate venturing or a non-compete agreement). On the other hand, yet another essential element of our analysis is that neither corporate venturing nor non-compete agreements can rule out an opportunistic sale of an idea (as this is not verifiable); the latter can only be prevented either through patents or through providing the inventor with a stake in revenues.

Our paper is also related to the general literature on enforcement of intellectual property rights, exclusivity and leakage of knowledge. Bessen and Meurer [2008] analyze imperfections in the patent system and show that in reality, patents do not provide perfect protection of intellectual property rights. In the absence of clearly defined property rights it is hard to provide strong incentives for inventors and researchers. Not surprisingly, only some industries rely on patents, while others use alternative mechanisms such as trade secrets. This argument is close to our analysis of choice of the mode of knowledge sale depending on the degree of leakage—and of the importance of corporate venturing for providing incentives for inventors.

III. THE MODEL

III(i). *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 unitsm,' 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 creation of a new product. If only one DU develops it successfully, he obtains a monopoly rent of $V = 1$ in the product market. If both DU's succeed in development, they compete *à la* Bertrand and each gets zero rent.

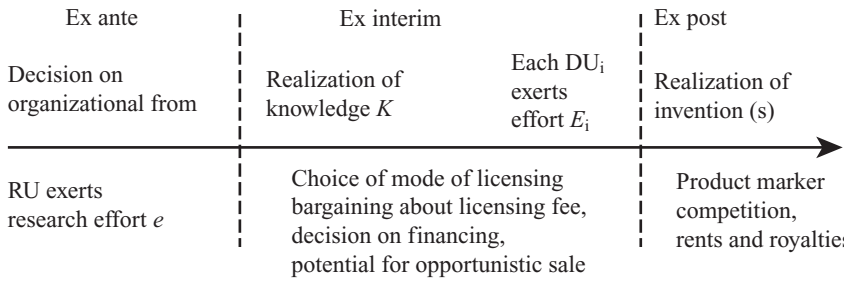

Figure 1
Timing

We assume that the RU does not have the financial resources to further develop the idea into the marketable product while both DU's do.

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 the *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 RU vs. Corporate Venturing) affects incentives for *ex ante* research.

We assume K to be a random variable with a cumulative distribution function $G(K; e)$ that depends on the RU's *ex ante* effort e. Subsequently, each DU exerts effort E which leads to the successful development with probability P.

Both efforts e and E are measured in terms of their costs, which are assumed to be non-verifiable. The cost of development effort is a function of both the induced probability of success P that RU wants to achieve and the available knowledge K: $E = C(P, K)$. The cost is increasing in P and decreasing in K. We assume that $C(P, K)$ is a neoclassical constant-returns-to-scale function,

$$(1) \qquad E = C(P, K) = Kc(P/K)$$

where function $c(\cdot)$ is an increasing and convex function: $c' > 0$, $c'' > 0$.

Without loss of generality we normalize K so that $c'(1) = 1$. In this case, knowledge level K is measured 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 we will have $P \leq K$. For the sake of simplicity we will focus on the Cobb-Douglas parametrization $c(P/K) = \alpha(P/K)^{1/\alpha}$ where $\alpha \in (0, 1)$.

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.

III(ii). *Timing and Assumptions*

The timing of events is as follows.

Ex ante, the parties choose an allocation of control rights: either (i) RU and DU's 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.[8] There are two alternative modes of knowledge licensing. One is based on patents (hereinafter we refer to it as the *open* mode), and the other is based on trade secrets (we refer to it as the *closed* mode).

Open mode. In the open mode, a patent on K is registered, so that the RU can commit to sell its knowledge to one buyer only. RU describes its knowledge publicly which leads to a partial leakage thereof;[9] an exogenous proportion $L \in 0, 1)$ of the capability K immediately becomes publicly available. Both DU's also infer the *level* of RU's knowledge K from this patent description. They are interested in getting the full content of invention K (rather than just the leaked knowledge $LK < K$).

RU then invites competing bids—sequentially, via rounds of offers alternating across the two DU's. We analyze an infinite horizon bargaining game, with parties having a common discount rate $\delta \to 1$. In the first round, a randomly chosen DU offers to pay the RU a lump-sum licensing fee F_o for an exclusive license for the full content of RU's knowledge.[10] If the RU rejects the offer, the other DU makes new offer. The game continues until DU_i's offer is not accepted. In this case, DU_i receives a license to use the full content of K while the competitor, DU_j, only has access to the leaked knowledge LK.

Once the bargaining is over, the licensing fees ends, the competing DU's then choose their efforts $\{E_i, E_j\}$ or, equivalently, probabilities of success $\{P_i, P_j\}$). The efforts and probabilities are related as follows: $E_i = C(P_i, K)$ and $E_j = C(P_j, LK)$. The effort choices constitute Nash equilibrium strategies in the post-licensing subgame between these two DU's.

[8] The bargaining game in each mode, with and without patenting, is sketched below; see Bhattacharya and Guriev [2006] for a more detailed description.

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

[10] We rule out patented sales to both DUs. As we discuss in Bhattacharya and Guriev [2006], in the setting with two DU's and *ex post* competition *à la* Bertrand, the non-exclusive licensing is always dominated from the RU's point of view by an exclusive sale to one DU. Therefore, the RU will agree to accept only exclusive licensing bids. The RU is better off with the exclusive sale, even when licensing to both DU's may increase total developers surplus ex interim. We discuss this issue in more detail in Section 5.

Closed Mode. In the trade-secret based mode, knowledge licensing occurs through a private sale of the contents of K to one of the DU's. If RU is independent, the buyer is randomly chosen by the RU. In the Corporate Venturing scenario, the buyer is the DU_i that has control rights over the RU.

The parties bargain bilaterally about their licensing contract. We assume that the parties have equal bargaining power, based on alternating offers *à la* Rubinstein [1982], for the RU and its chosen licensee DU. In the process of the bargaining, the RU describes its invention to DU_i which results to a leakage of LK to it. If the parties do not agree, RU can start bargaining with the competing DU_j (but DU_i keeps this leaked knowledge LK).[11] If the parties agree (and DU_i gets the full content K), the RU may still make a clandestine second sale of the knowledge K to the competing DU_j.

The parties (RU and the DU_i) can sign a contract contingent on DU_i's post-invention revenues. 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. After RU and DU_i agree on these terms of licensing, the RU reveals the full content of its knowledge to the licensee DU_i. The buyer DU_i then chooses its 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_i is structured so that the RU does not sell its knowledge to the competing buyer DU_j in equilibrium. Therefore, in order to understand the structure of the contract, we need to describe the out-of-equilibrium second sale by RU. In this case, the RU would first describe its knowledge to DU_j; this would cause leakage LK. If they agreed on a fee for the RU's disclosing the full content of its 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 the idea on the basis of leaked knowledge LK; in this case we denote its choice of probability of invention as Q_d. By choosing RU's revenue share s appropriately, DU_i will try to prevent the RU's disclosing its 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.

The contract structure above is general in the sense that it includes all contracts contingent on verifiable outcomes. As we only have two *ex post* outcomes (V = 0 and V = 1), any contract can be written as a combination of two elements $\{X_0, X_1\}$ where X_0 is the payment in case of $V = 0$ and X_1

[11] 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 its knowledge, contingent on any disagreement with its potential licensee DU.

is the payment in case of $V = 1$. Therefore this contract is equivalent to a combination of a fixed fee $F = X_0$ and the contingent royalty $s = X_1 - X_0$. This is exactly the contract structure in the closed mode (we will prove below that s in equilibrium should be between 0 and 1). In the open mode, we—for simplicity's sake—exclude the contingent part. As is clear from the analysis below, a positive royalty stake $s > 0$ is inefficient: it undermines the incentives of the licensee DU (that only gets to keep $1 - s$ of the *ex post* surplus) without adding incentives to the RU. Indeed, in the open (patent-based) mode, clandestine sale to a competing DU is ruled out due to patent enforcement; there is no need to give the RU a share s in *ex post* revenues. Therefore, in the open mode no contract can outperform a fixed-fee contract $X_0 = X_1 = F$.

III(iii). *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

$$U_{oi} = [(1 - P_j)P_i - C(P_i, K) - F_o] \tag{2}$$

$$U_{oj} = [(1 - P_i)P_j - C(P_j, LK)] \tag{3}$$

The RU receives F_o.

In the subgame perfect equilibrium of the bargaining game, the bargaining stops in the first round. The licensing fee F_o is such that the DU_i is indifferent between getting the patented knowledge with the payoff U_{oi} and developing based on the leaked knowledge and receiving the payoff U_{oj}.

If the closed model of knowledge sale is chosen, the licensee DU obtains:

$$U_c = [(1 - s)P_c - C(P_c, K) - F_c] \tag{4}$$

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.

III(iv). *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 its licensee DU. We will denote as T_c

and T_o the joint *ex interim* surplus of the RU and its 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 (2). The efforts of the competing DU's (measured in terms of probabilities of successful development $\{P_o, Q_o\}$) satisfy the Nash equilibrium conditions:

$$c'(P_o/K) = 1 - Q_o, \tag{5}$$

$$c'(Q_o/LK) = 1 - P_o. \tag{6}$$

The two equations above are the first order conditions of DU_i's and DU_j's maximising their objective functions (2) and (3) with regard to P_i and P_j, respectively. (To obtain (5)–(6), we simply differentiate (2)–(3) and use (1)). In both cases, the objective function is concave, and the first order condition is necessary and sufficient.

Both T_o and P_o increase with K, P_o decreases with L, Q_o increases in L. F_o is increasing in K and decreasing in L.

Essentially, the sequential offers bargaining process in this mode results in Bertrand competition between the two DU's: the RU extracts all the surplus of the licensee DU_i, making his net payoff equal to that of the non-licensee DU_j. The equilibrium payoffs of the RU and DU, characterized in Bhattacharya and Guriev [2006], are as follows:

$$\begin{aligned} T_o &= K[(1-Q_o)P_o/K - c(P_o/K)]; \\ U_o &= T_o - F_o = LK[(1-P_o)Q_o/(LK) - c(P_o/(LK))] \end{aligned} \tag{7}$$

where P_o, Q_o solve (5)–(6).

Under the assumptions above, for each pair of $K \in [0, 1]$ and $L \in [0, 1]$ the system (5)–(6) has a solution. Indeed, the first condition (DU_i's reaction function) specifies a monotonically decreasing relationship between P_o and Q_o that includes pairs $P_o = 0$, $Q_o = 1$ and $P_o = K$, $Q_o = 0$. Similarly, the second condition (DU_j's reaction function) specifies a monotonically decreasing relationship that includes pairs $P_o = 0$, $Q_o = LK$ and $P_o = 1$, $Q_o = 0$. Therefore, the two reaction curves necessarily intersect at some $P \in [0, K]$.[12]

[12] Another way to prove existence is to note that the Nash equilibrium $\{P_o, Q_0\}$ is actually a solution to the social surplus maximization problem $\max_{P_o, Q_0} 1 - (1-P)(1-Q) - C(P_o, K) - C(Q_o, LK)$.

In the case where there are multiple equilibria, we will use the straightforward equilibrium selection criterion—we will choose the equilibrium that maximises the RU's licensing fee $F_o = [(1 - Q_o)P_o - C(P_o, K)] - [(1 - P_o)Q_o - C(Q_o, LK)]$. Since the two DU's effectively compete *à la* Bertrand, they will offer the RU the highest possible payoff. Then, once the licensing fee F_o is set, playing a different equilibrium would result in the licensee DU's receiving a lower payoff than the non-licensee DU.

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 the 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:

$$sP_c - sP_c(1-P_d) \geq \{(1-P_c)P_d - C(P_d, K)\} - \{(1-P_c)Q_d - C(Q_d, LK)\} \tag{8}$$

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 it. P_d is chosen by DU_j if it has full knowledge, and Q_d is its choice with leaked knowledge LK. Respectively, for a given contract structure, these choices solve the following optimisation problems:

$$\max_{P_d}(1-P_c)P_d - C(P_d, K) \tag{9}$$

$$\max_{Q_d}(1-P_c) - C(Q_d, LK) \tag{10}$$

$$\max_{P_c}(1-s)P_c - C(P_c, K) \tag{11}$$

For a given share s, the left-hand side in (8) is the reduction in the RU's expected royalty payoff due to opportunistic disclosure to DU_j.

The right-hand side of (8) is the maximum licensing fee that RU may extract from DU_j, in case it decides to disclose to DU_j after licensing its 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 (8) 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 its 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 exert effort. Indeed, by solving (9)–(11) for optimal effort of DU_j and DU_i we find that P_c decreases in s:

$$c'(P_d/K) = 1 - P_c \tag{12}$$

$$c'(Q_d/(LK)) = 1 - P_c \tag{13}$$

$$c'(P_c/K) = 1 - s \tag{14}$$

In equilibrium, RU and DU_i will choose the minimum possible $s \in [0, 1]$ that satisfies the incentive constraint (8). Therefore this constraint should be binding.

The royalty stake s should be between 0 and 1. First, s cannot be negative—in this case (8) would not hold. Indeed, in that case the left-hand side of (8) $sP_c - sP_c(1 - P_d) = sP_cP_d$ would be negative. At the same time, the right-hand side of (8) is non-negative ($L \leq 1$ implies $Q_d \leq P_d$). The same logic implies that s can only be zero in the extreme case of full leakage $L = 1$. Can the royalty stake exceed 100% ($s \geq 1$)? This is also impossible as this would imply $P_c = 0$ (see (11) and (14)). This would make the left-hand side of (8) equal to zero so (8) would again be violated unless there is a complete leakage $L = 1$.

For the Cobb-Douglas function $c(x) = \alpha x^{1/\alpha}$, we substitute (12)–(14) into (8) and find

$$s = (1-\alpha)(1-L)\left(\frac{1}{K}(1-s)^{-\frac{\alpha}{1-\alpha}} - 1\right). \tag{15}$$

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 the RU to be given a (minimum) share $s = s^*(K; L)$ in its licensee DU's post-invention revenues, where $s^*(K, L)$ solves (15). 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 the RU and the licensee DU is

$$T_c = P_c - C(P_c, K) = K\left[(1-s^*(K;L))^{\frac{\alpha}{1-\alpha}} - \alpha(1-s^*(K;L))^{\frac{1}{1-\alpha}}\right]. \tag{16}$$

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.

The Lemma extends and generalizes the results in Bhattacharya and Guriev [2006]. The intuition is as follows. The closed mode does not have to be feasible for all parameter values (see the full analysis of existence and non-existence for $\alpha = 1/2$ in Bhattacharya and Guriev [2006]). Indeed, it may be the case that there is no royalty contract s for which the incentive compatibility constraint (8) holds. The analysis of (15) immediately shows that the closed mode is more likely to exist when both K and L are high. If the leakage is high, the right-hand side of (8) is lower and it is easier to incentivize the RU not to disclosed to a competing DU. Why is this the case? The reason is that if the RU sells to the competing DU, it will not be able to charge a high fee—indeed, the leakage will have undermined the value of the knowledge to the competing DU. Therefore the RU will have lower incentives to deviate—and it is easier to provide such incentives even with a lower royalty s. And the lower the royalty, the higher the incentives to develop P_c, the greater the joint surplus.

Similarly, if the quality of the idea K is high, it is easy to satisfy the incentive compatibility constraint. The more valuable the idea, the greater the total pie (for the RU and the licensee DU to share). Since the licensee DU develops on the basis of the full knowledge K and the threat of deviation is about creating a competition between two developing DU's, the difference is higher the greater the knowledge K. Once again, this creates additional incentives for the RU not to divulge knowledge even for lower royalty stakes s. Thus the more valuable the idea, the lower royalty stake s it takes to prevent opportunistic second sale, and the higher the joint surplus.

The fact that the *value* of the royalty stake sP_c decrease in K is less obvious. Indeed, while the stake s decreases in K, the effort and the probability of success P_c certainly increase in K. What happens to the product of the two? The incentive compatibility constraints implies that the value of the royalty stake is proportional to the differences between DUs' payoffs $\{(1 - P_c)P_d - C(P_d, K)\} - \{(1 - P_c)Q_d - C(Q_d, LK)\}$ divided by P_d. In our constant returns to scale specification (1) all payoffs eventually are proportionally to K, so for a given P_c the level of knowledge cancels out:

$$\frac{(1-P_c)P_d - C(P_d, K)}{P_d} - \frac{(1-P_c)Q_d - C(Q_d, LK)}{P_d}$$
$$= \frac{(1-P_c)p_d - c(p_d)}{p_d} - L\frac{(1-P_c)q_d - c(q_d)}{p_d}$$

where $p_d = P_d/K$ and $q_d = Q_d/K$. Intuitively, the right-hand side of (8) is proportional to the competitive pressure $1 - P_c$ from DU_i on the competing

DU. The higher the value of the knowledge K, the higher the effort of the licensee DU_i and the lower the potential payoffs of the competing DU_i (the game of post-invention development is a game with strategic substitutes). And the lower is the the right-hand of (8), the lower is the value of the royalty stake given to RU in equilibrium.

Once we established that the joint surplus increases in the value of the idea K and the value of the royalty stake sP_c decreases in K, we immediately find that the lump-sum fee $F_c = T_c - sP_c$ increases in K.

The Lemma shows that the closed mode is more efficient than the open mode—and therefore is more likely to be chosen—whenever the idea is valuable (K is high) and the leakage L is high. Intuition for this is straightforward: the higher the knowledge K and the higher the leakage L, the more intensive is the effort by a competing DU_j in the open mode. Hence, the licensee DU_i's payoff is lower. Furthermore, the higher the ultimate value of knowledge K, the lower the royalty stake s, hence it is easier to provide the RU with incentives for trade secrecy without distorting DU's incentives. Similarly, higher leakage L also helps to sustain the closed mode—as the breach of secrecy results in a costlier outcome.

IV. CONTROL RIGHTS AND *EX ANTE* INCENTIVES

The results above neglect the RU's *ex interim* financial constraint. At the same time, the Lemma helps understand when the financial constraint is likely to be binding. The lower the value of the idea K, the lower the total surplus T_c and the higher the equity stake sP_c required to sustain the closed mode. Therefore, the lower K, the lower the lump-sum fee $F_c = T_c - sP_c$; once this lump-sum payment becomes negative, the RU's financial constraint is binding. The level of the RU's required revenue share s to ensure an exclusive closed-mode sale is so high that the RU has to make a lump-sum payment to its licensee DU_i to persuade DU_i to choose the closed mode ($F_c < 0$). This is the case when the value of knowledge K is sufficiently low.

The 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—because of the RU's financial constraint. This disagreement occurs whenever $(T_o - F_o) > (T_c - sP_c)$. If the RU had deep pockets, it 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 it has some external source of financing.

This inefficiency creates a role for allocation of control rights. We will now consider two scenarios of *ex ante* allocation of control. First, we study 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 commits *ex ante* to remain financially constrained *ex interim*, through giving control rights to DU_i. This commitment rules out third-party financing *ex interim* and therefore results in *ex interim* inefficiency. On the other hand, since this inefficiency is more likely to arise for lower K, the RU has stronger incentives to exert effort *ex ante* to increase K and avoid such outcomes.

Independent Inventor. If the RU is independent and requires external financing *ex interim*, it may join forces with a venture capitalist (VC) who will provide cash to pay the licensee DU_i the amount

$$I = (T_o - F_o) - (T_c - sP_c) \tag{17}$$

ex interim, in exchange of I/P_c shares out of the s share of DU_i's revenue.[13] It is crucial that such a VC is able to ensure that RU acts in the interest of their RU-VC coalition. Therefore the RU does not disseminate knowledge to DU_j even though it 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 engaged in repeated transactions with various inventors. Therefore VC's reputational concerns should prevent opportunistic behavior by its coalition partner (whom VC will closely monitor).

Corporate Venturing. The second scenario is corporate venturing. Formally, the game is structured as follows.

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. RU and DU_i sign a contract *ex ante*, stating that if RU signs any financial contracts with outsiders, the partner VC must pay DU_i a sufficiently high penalty for a breach of the *ex ante* agreement with DU_i. Also, RU is required to start negotiations with DU_i first and is not allowed to sell its knowledge to a competing DU_j exclusively. We assume that 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 VC is by definition verifiable (this is especially realistic if the VC's reputation is valuable).

After the contract on the allocation of control (that includes vetoing outside financing) is signed, RU undertakes research effort. Then the level of knowledge K is realised.

[13] As there are only two *ex post* outcomes, there is no distinction between debt and equity financial contracts.

Ex interim, the parties enter bargaining on the choice and terms of licensing mode. At this moment, parties can renegotiate: RU can also ask DU_i to give up the control rights (i.e. nullify the *ex ante* contract) in exchange for a payment. Notice that RU cannot pay immediately (as it is financially constrained). If the DU disagrees, the outside financing is still vetoed (and fined); RU and DU_i choose the closed mode or the open mode without attracting outside financing. In particular, if the closed mode is efficient but is ruled out because of the RU's binding financial constraint, the parties resort to the open mode.

DU_i can also agree to relinquish control rights *ex interim*. In this case, RU can go to an independent VC for financing and then is free to choose either DU_i or DU_j for licensing. This outcome never happens in equilibrium. Preserving control rights and lack of outside financing is renegotiation-proof. Let us illustrate it in the most interesting case for—when the closed mode is efficient (in terms of RU-DU_i's joint surplus) but not feasible (because of RU's financing constraint) so that the parties choose the open mode. Why cannot the parties renegotiate away this inefficiency? The renegotiation breaks down—exactly because of the very same financial constraint. The financing constraint does not allow RU to pay for giving up the control rights right away (and RU cannot make a binding promise to DU_i about any prospective payment). Furthermore, RU cannot raise cash for relaxing the financial constraints as the *ex ante* contract between RU and DU_i foresees a large penalty to be paid to DU_i for any third-party financing Therefore our notion of DU's control rights is renegotiation-proof: *ex interim*, DU has no incentive to relax its control rights and allow independent financing of RU.

Why would parties want to sign such a contract that involves committing to *ex interim* inefficiency? The reason is that although the independent RU scenario is efficient *ex interim*, it may provide the 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 does create *ex interim* inefficiencies but also enhances RU's *ex ante* incentives to invest in research leading 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 trade-off in the context of a simple set up where RU can choose one of two effort levels: high or low. The high level of effort costs her e dollars more. The high level of effort delivers higher knowledge $K = K^H$ *ex interim* with probability ξ_1 and $K = K^L$ with probability $1 - \xi_1$, where $K^L < K^H$. If the effort level is low, the high state $K = K^H$ takes place with probability ξ_0 where $0 < \xi_0 < \xi_1 < 1$.

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 condition 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 venturing matters in the low state.

Let us now compare the RU's incentives to exert effort under the two scenarios. If RU is independent, a high level of effort brings additional $(\xi_1 - \xi_0)[\max\{T_c^H/2, F_o^H\} - (s^L P_c^L - I^L)]$ at a cost e. In the corporate venturing scenario, parties end up in the (inefficient) open mode; by exerting high level of effort, RU gets additional $(\xi_1 - \xi_0)[\max\{T_c^H/2, F_o^H\} - F_o^L]$—also at the cost e. Therefore we arrive at the following

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

$$\max\{T_c^H/2, F_o^H\} - \frac{e}{\Delta\xi} < s^L P_c^L - I^L \text{ and} \tag{18}$$

$$\max\{T_c^H/2, F_o^H\} - \frac{e}{\Delta\xi} > F_o^L, \tag{19}$$

where $\Delta\xi = \xi_1 - \xi_0$. Corporate venturing will be adopted *ex ante* if the change in research effort is cost-efficient:

$$\left(T_c^H - \frac{e}{\Delta\xi}\right) - T_c^L > 0. \tag{20}$$

Whenever (18)–(19) hold, the effort is low in the independent VC scenario but is high in the corporate venturing scenario.

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 (18)–(19) are consistent for a range of effort costs e.

V. ROBUSTNESS

In order to make our analysis tractable, we have made a number of simplifying assumptions. In this section we discuss how robust our conclusions are to changes in the setting.

First, we assumed that *ex post* firms compete *à la* Bertrand with homogenous goods. In particular, if only one firm makes a successful invention, it earns the monopoly rent normalized to 1: $V = V_M = 1$; if neither firm

invents, both get zero; if both firms invent, the duopoly profit is also zero: $V_D = 0$. What would happen in a more general setting where duopolists would make a positive profit? Let us consider the case where each duopolist earns some $V_D > 0$ (we should still assume that $V_D < V_M/2 = 1/2$). In this case, the knowledge leakage to the competitor is less painful—as the loss of monopoly power costs only $V_M - V_D$ rather than V_M. Therefore, the closed mode is harder to sustain. Vice versa, the open mode is more attractive. Indeed, the patenting DU in the open mode receives $U_{oi} = (1 - Q_o)P_o - C(P_o, K)) + V_D P_o Q_o$ and its competitor gets $U_{oj} = (1 - P_o)Q_o - C(Q_o, LK)) + V_D P_o Q_o$. It is easy to prove that in this case both DU's will exert more effort, and the joint surplus will also increase. This follows from the fact that the competing DUs' efforts are strategic substitutes: the marginal returns to investment decrease in the other DU's effort: $\partial^2 U_{oi}/(\partial P_o \partial Q_o) = -1 + V_D < 0$. Therefore, each DU's best response is a decreasing function of the other DU's effort but increases in the duopolists' profits V_D. A higher V_D thus raises equilibrium levels of both P_o and Q_o. Thus in a more general case with non-trivial duopoly profits V_D the parties are more likely to choose the patent-based (open) mode rather than the royalty-based (closed) mode. This implies that the need to rely on corporate venturing is less likely.

What would change if we also consider the case where the DUs' investments are strategic complements rather than strategic substitutes?[14] In this case each DU *benefits* from the other DU's investment. Not only does leakage of knowledge to a competitor become less costly (as in the case with $V_D > 0$), it actually brings positive benefit. In this case, closed mode is never chosen and corporate venturing is irrelevant. Moreover, when parties negotiate *ex interim* they know that the joint surplus increases in the amount of leaked knowledge—therefore they will be interested in giving a license to each DU. In other words, the main insights from our original setting (which we consider more realistic) do not extend to the case of strategic complements.

Yet another implication of the change in the structure of the *ex post* market competition could be the emergence of non-exclusive licensing in equilibrium. If duopolists have positive profits and especially if there are more than two potential DU's, then the inventor can extract greater revenues from selling two rather than one licence. While the total *ex post* profits would still be higher in the case of monopoly, the *ex interim* surplus

[14] One simple example would be to replace the setting where DU's invest in probabilities of invention with the setting where invention is certain but DU's invest in the quality of this invention. For example, suppose that DU_i's *ex post* profit is $p_i(P_o - p_i + ap_j)$ where p_i, p_j are prices set *ex post*, P_i is the DU_i's *ex interim* investment and a is a parameter of the demand system. In this case, the *ex post* profit of DU_i is $\left(\frac{2P_o + aQ_o}{4 - a^2}\right)^2$; the competing DUs' investments are strategic complements. Moreover, DU_i's *ex post* profit increases in DU_j's investment Q_o.

of RU may be higher in the case of duopoly. Indeed, suppose there are three potential DU's. In this case, non-exclusive licensing brings the RU the licensing fee equal to the difference between *ex interim* payoff of the licensee DU and that of the non-licensee DU's. Notice that since in the the setting with three DU's there are two non-licensee DU's who participate in the development race based on leaked information (LK), the *ex interim* payoff of the licensee DU is lower than in the case where there only two DU's in total. Let us now consider the situation with two licensees. Here the RU receives a licensing fee twice—one from each licensee DU. The licensing fee will be once again a difference between the *ex interim* payoff of a licensee DU and that of the non-licensee DU. While this difference is smaller than in the case of exclusive license, the RU may still prefer this scenario as it gets the fee twice. While the full analysis of this case remains an interesting avenue for further research, we can speculate that such extension will make the open mode more attractive and therefore reduce the incentive effects (and therefore prevalence) of corporate venturing.

Throughout the paper, we use a Cobb-Douglas technology $E = C(P, K) = \alpha K(P/K)^{1/\alpha}$.[15] Most results hold for more general functional forms as well, for example a general neoclassical constant-returns-to-scale technology $E = C(P,K) = Kc(P/K)$, where $c(P/K)$ is a neoclassical cost function. We only used the specific functional form to describe the solutions in the open and in the closed mode. For the general functional form, the solutions still exist (although they cannot be pinned down analytically as in (15)), and their properties are still the same. In particular, the closed mode is more likely to exist and more likely to be efficient than the closed mode when knowledge K is high and leakage L is high. The other comparative statics results from Lemma 1 also hold—thus implying the main result on corporate venturing, Proposition 1. For the general form however we cannot prove the uniqueness of equilibria in either open or closed mode. This raises important questions about selection of equilibria (in the open mode we can assume that RU chooses the equilibrium with the highest licensing fee F_o, in the closed mode the parties should choose the equilibrium with the lowest possible royalty stake s as this results in minimum distortion).

Finally, one can raise the issue of the asymmetry of financial constraints. We assumed above that the RU can be financially constrained but not the DU. We believe that this is a realistic assumption: usually the earlier stage innovators are smaller and have shallower pockets. But what would happen if we also consider the DU's financial constraints? In this case, it would be harder for parties to implement the open mode (where the DU has to pay the whole licensing fee upfront). Thus, the DU's financial constraints are likely to make the closed mode more likely.

[15] This is equivalent to the production function of probability of success being $P = \frac{1}{\alpha^\alpha} E^\alpha K^{1-\alpha}$.

VI. EMPIRICAL IMPLICATIONS

The empirical implications of our results are as follows. Controlling for quality of research, industry and size, internal corporate venturing should result in greater prevalence of patenting rather than trade-secret-based 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 of interim ideas is not viewed as the preferred mode of protecting intellectual property rights over these (e.g., owing to high leakage of non-codifiable aspects of the knowledge involved).

However, straightforward search for correlations between patenting and corporate venturing may be misleading. Indeed, in our model, it is the controlling DU's credible threat of forcing RU's to patent lower-quality ideas (via denial of access to third party external financing) that increases incentives to invent more valuable ideas. In equilibrium, we may actually fail to observe patenting of lower-quality inventions. In this case we may find that inventors sponsored by independent VC's patent more. Therefore, convincing empirical support for our thesis would depend on identification of an exogenous source of variation of IPR protection across sectors or countries. In case—all other things equal—patents are less enforceable in firm/sector/country A than in B, we should see less corporate venturing (as the threat of forcing to patent is less credible). Such an empirical study seems to be doable although we are not aware of any attempts to carry it out.

Another source of exogenous variation for testing our theory is bankruptcy legislation. While it may be somewhat endogenous to the evolution of innovative industries, bankruptcy codes are driven by economy-wide factors. Acharya and Subramanian [2009] conduct an extensive cross-country and cross-sectors empirical analysis of the effect of bankruptcy laws on innovation. Their theoretical and empirical results suggest a thesis seemingly counter to ours. They suggest, and provide supporting empirical evidence for, a beneficial impact of 'soft,' or debtor-friendly, residual control rights in the bankruptcy process, that is greater for firms and industries which they classify as being more innovative based on patents as well as citation counts. This effect is shown by Acharya and Subramanian to hold across countries, as well as over time in response to changes in bankruptcy laws, after adjusting for other effects such as dependence on external financing, and the extent of financial development.

It turns our however that our argument is consistent with their empirical results, although we have a different mechanism in mind. In essence, Acharya and Subramanian argue in their modeling that greater control rights of debtor firms regarding continuation of investment in projects with initially disappointing returns, result in relatively higher efficiency gains for innovative firms. In these firms, lower early returns are more likely, but

even moderate early returns augur significantly higher later returns, as compared to non-innovative (conservative, or low-risk) lines of investment. In the Acharya and Subramanian model, this effect arises from frictions in debt rescheduling.

There is a connection between our thesis, relating to the potential impact of third-party outside financing for the interim efficiency of the licensing of innovation, and their results on the differential impact of debtor-friendly laws or regimes in handling bankruptcy for more innovative firms and sectors relative to 'traditional' sectors. Specifically, we may think of such a debtor-friendly regime as being supportive of *debtor-in-possession financing*, as in the U.S. Chapter 11. Let us consider a modification of our model that would bring it closer to Acharya and Subramanian's. Suppose that the *ex ante* research effort may yield two (mutually exclusive) potential paths for further development. The optimal strategy is to proceed first with the initially more promising path, entailing a maximal success probability K^H, with costly development requiring external financing leading to a chosen probability P^H of success.

If this first path of development fails, then the firm that tried to develop it is still left with the intellectual property of the other potential path of development. Suppose that this other path entails the (possibly revised) maximal success probability $K^L < K^H$. However, the level of debt overhang from the failed first development effort is too high for that developer to credibly invest in the second line of invention. Hence, it needs to license this innovative idea to another DU, and the surplus-maximizing mode of doing so, which is also important for the maximization of *ex ante* research incentives, is the closed or trade-secret based one. However, as we discussed above, to do such licensing in an incentive compatible way for a lower level of knowledge K^L may require the aid of a third-party (specialized) outside financier. The outside funding is needed to advance the amount of funds I_c required for the licensor to give the bankrupt DU the requisite revenue or royalty share. It is also likely that a new financier would be willing to do so if and only if its claim to these potential royalties in future is senior to those of the pre-existing creditors who financed the failed first effort.

Allowing debtor-in-possession financing in these contingencies would clearly be of help. Note that our line of advocacy for debtor-friendly bankruptcy laws in circumstances like the above is based on the need to enhance the interim efficiency of the *disposal* of residual intellectual property of the bankrupt firm. Our argument does not require the fixity of the claims of other creditors, nor does it assume that it is the insolvent firm which would somehow continue in the same line of business. What it does presuppose is that the idea involved in the initially failing invention process is *multi-faceted*, affording more than one possible line of development with different ranges of outcomes, even products. For example, consider

transistors in the early stages, when its inventors left AT&T, the firm within which the initial innovation occurred, to pursue other lines of application.

Such a multi-faceted characteristic of innovative ideas is perhaps more likely to be true in the sectors commonly labeled the 'new economy,' in which their technological possibilities and frontiers, and lines of application, are not yet fully discernible. In contrast, even innovative ideas in more traditional 'old economy' sectors might be on average more unidimensional: an idea either succeeds for its envisaged application post development, or it fails and has no other use. However, ideas still differ in their qualities, measured as the maximal probability of their successful development, and higher quality ideas are generated (made more likely) only with greater costly *ex ante* effort. In such sectors, the control aspect of corporate venturing, via its impact on generating incentives for research units to undertake such effort, may matter more.

As an empirical matter, some patent citation-based measure, such as 'patent generality,' might usefully serve to capture the multi-faceted characteristics of innovative ideas. It would be interesting to study whether the prevalence of institutions such as corporate venturing–as opposed to independent VC financing–across diverse sectors of an economy, is correlated with such a characteristic, as well as with more commonly studied (qualitative) features, such as the extent of leakage from disclosure in patents.[16]

VII. CONCLUDING REMARKS

In this paper, we have elucidated a theory of control rights in the context of licensing intellectual property, which is consistent with the inalienability of the initial innovator's human capital. 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 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.[17]

Unlike in the earlier paper of Aghion and Tirole [1994], which deals (ostensibly) with bargaining and control rights in a context of sequential

[16] Our model also implies desirability of sector-specific variation in bankruptcy rules with softer rules for the 'new' sectors. In principle, sector-specific bankruptcy rules are already included in the Chapter 11 (e.g., Section 11.10), albeit for a different reason.

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

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).[18] In our setup, an upstream RU always retains the right to patent its IP and invite competing bids for its licensing from all DU's, as well as that of bargaining with the controlling DU about the terms of trade-secret-based licensing. Our corporate venturing DU obtains only the control rights of (i) the first offer, with 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 their recent work on incomplete contracts and control, Hart and Moore [2008] 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 IV, 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 and partner.

REFERENCES

Acharya, V. and Subramanian, K., 2009, 'Bankruptcy Codes and Innovation,' *Review of Financial Studies*, 22(12), pp. 4949–4988.

Aghion, P. and Tirole, J., 1994, 'On the Management of Innovations,' *Quarterly Journal of Economics*, pp. 1185–1209.

Anand, B. and Galetovic, A., 2000, 'Weak Property Rights and Holdup in R&D,' *Journal of Economics and Management Strategy*, 9, pp. 615–642.

Anton, J. and Yao, D., 1994, 'Expropriation and Inventions—Appropriable Rents In the Absence of Property Rights,' *American Economic Review*, 84, pp. 191–209.

Belenzon, S. and Schankerman, M., 2013, 'Spreading the Word: Geography, Policy and Knowledge Spillovers,' forthcoming in *Review of Economics and Statistics.*

Berglof, E., 1994, 'A Control Rights Theory of Venture Capital Finance,' *Journal of Law, Economics and Organization*, 10, pp. 247–267.

Bessen, J. and Meurer, M., 2008, *Patent Failure: How Judges, Bureaucrats and Lawyers Put Innovation at Risk.* (Princeton University Press, Princeton, New Jersey, U.S.A.)

[18] We consider our approach realistic. The researchers often manage to appropriate a substantial share of the surplus. 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].

Bhattacharya, S. and Guriev, S., 2006, 'Patents vs. Trade Secrets: Knowledge Licensing and Spillover,' *Journal of the European Economic Association,* 4(6), pp. 1112–1147.
Casamatta, C., 2003, 'Financing and Advising: Optimal Financial Contracts with Venture Capitalists.' *Journal of Finance*, 58, pp. 2059–2085.
Chesbrough, H., 2002, 'Graceful Exits and Missed Opportunities: Xerox's Management of Its Technology Spin-off Organizations,' *Business History Review*, 77, pp. 803–837.
Cohen, W.; Nelson, R. and Walsh, J., 2000, 'Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not),' NBER working paper, no. 7552 (National Bureau of Economic Research, Cambridge, Massachusetts, U.S.A.)
Dushnitsky, G., 2006, 'Corporate Venture Capital: Past Evidence and Future Directions,' in Casson, Yeung, Basu & Wadeson (eds.) *Oxford Handbook of Entrepreneurship*, (Oxford University Press, Oxford, England).
Featherstone, J. and Renfrey, S., 2004, 'Licensing Gambles: Raising the Stakes,' *Nature Reviews: Drug Discovery*, 3, pp. 107–108.
Gompers, P. and Lerner, J., 2000, 'The Determinants of Corporate Venture Capital Successes: Organizational Structure, Incentives, and Complementarities,' in R. Morck (ed.), *Concentrated Corporate Ownership*. (University of Chicago Press, Chicago, Illinois, U.S.A.)
Gompers, P., and Lerner, J., 2004, *The Venture Capital Cycle*, 2nd ed. (MIT Press, Cambridge, Massachusetts, U.S.A.)
Hart, O., 1995, *Firms, Contracts, and Financial Structure*. (Oxford: Clarendon Press, Oxford, England).
Hart, O. and Moore, J., 2008, 'Contracts as Reference Points,' *Quarterly Journal of Economics*, CXXIII(1), pp. 1–48.
Hellmann, T., 1998, 'The Allocation of Control Rights in Venture Capital Contracts,' *RAND Journal of Economics*, 29(1), pp. 57–76.
Hellmann, T., 2002, 'A Theory of Strategic Venture Investing,' *Journal of Financial Economics*, 64, pp. 285–314.
Hellmann, T., 2007, 'When Do Employees Become Entrepreneurs?' *Management Science*, 53(6), pp. 919–933.
Hunt, B. and Lerner, J., 1995, 'Xerox Technology Ventures,' Harvard Business School case 9-295-127. (Harvard University, Cambridge, Massachusetts, U.S.A.)
Kaplan, S. and Stromberg, P., 2003, 'Financial Contracting Theory Meets the Real World: Evidence from Venture Capital Contracts,' *Review of Economic Studies*, 70, pp. 281–315.
Kortum, S. and Lerner, J., 2000, 'Assessing the Contribution of Venture Capital to Innovation,' *RAND Journal of Economics*, 31, pp. 674–692.
New York Times, 2004, 'Inventor Wins a Round in Tokyo Court,' Jan. 31, 2004.
Marx, M., Strumsky, D. and Fleming, L., 2009, 'Mobility, Skills, and the Michigan Non-Compete Experiment,' *Management Science*, 55(6), pp. 875–889 .
Noeldeke, G. and Schmidt, K., 1998, 'Sequential Investments and Options to Own,' *RAND Journal of Economics*, 29, pp. 633–653.
Rubinstein, A., 1982, 'Perfect Equilibrium in a Bargaining Model,' *Econometrica*, 50, pp. 97–111.
Wood Mackenzie, 2004, 'Licensing Insight 04,' (Wood Mackenzie Consulting, Boston Massachusetts, U.S.A., and Edinburgh, Scotland).