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ABSTRACT

Venture Capital, Patenting, and Usefulness of Innovations*

We analyze incentives to develop entrepreneurial ideas for venture capitalists (VCs) and incumbent firms. If VCs are sufficiently better at judging an idea's value and if it is sufficiently more costly to patent low than high value ideas, VCs acquire valuable ideas, develop them beyond the level incumbents would have chosen, and use patents to signal their companies' high value to acquirers prior to exiting. This increases the VC-backed companies' patenting intensity and long-run performance, but also inflates their acquisition prices, and lowers their acquirers' overall profits. Patent law usefulness clauses would reduce such excessive, signaling-driven investment and patenting intensity.

JEL Classification: C70, D21, D82, G24, L26, M13, O31 and O34
Keywords: innovation, patent law, patenting intensity, preemptive vs late acquisition strategies, signaling, usefulness requirement and venture capital

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1 Introduction

Angel investors contribute about 20 billion U.S. dollars every year to the financing of approximately 50,000 early-stage entrepreneurial ventures throughout the United States; venture capitalists add another 20 billion U.S. dollars of investment in approximately 2,800 entrepreneurial ventures.[1] Contrary to incumbents in an industry, which often acquire early-stage entrepreneurial companies to commercialize their ideas, angels and venture capitalists finance early-stage companies with the intent to exit their investment by selling their share of the companies' stock. Because of considerable uncertainty about the wealth-creating capacity of entrepreneurial companies, venture capitalists and angels have an incentive to signal their companies' value to potential acquirers prior to exiting.

By requiring innovations to be "useful" or "to have likely industrial applicability" for them to be patentable, the patent system creates an opportunity for investors to signal their companies' wealth-creating capacity by means of their patenting intensity.[2] We show that this signaling opportunity induces venture capitalists and angel investors (from now on, we will only write venture capitalists, or VCs, representing also other independent investors, such as angel investors) to invest more than incumbents in order to increase patenting intensity. This excessive investment improves their companies' long-run performance. However, it also increases both investments costs and acquisition prices that acquirers of their companies have to pay to such an extent that the acquisition of VC-backed companies is less profitable than other private acquisitions; and it would, therefore, induce a less positive reaction of the stock market to VC-backed than to other private acquisitions. Because the venture capitalists' excessive R&D investment dissipates resources, it can have a negative effect on productivity growth despite the higher patenting (and R&D investment) intensity.

We show that VC financing is more likely if it is more difficult to patent early-stage

[1]Source: Presentation of angel investor Bill Payne at Massey University on June 8, 2010.

[2]Our focus on the signaling function of patenting does not exclude other motivations for it, such as the protection of intellectual property against imitation. As venture capitalists or angel investors eventually sell their companies to a firm in the product-market or let their companies enter the product-market themselves, the extent of their patenting activity originating in these motivations is assumed to be the same as for other investors, such as incumbents.

innovations and if strict usefulness clauses in the patent law are implemented.[3] We also predict that tightening the implementation of such usefulness clauses (i) decreases the VC-backed companies' investment in development as well as their patenting intensity; (ii) decreases the VC-backed companies' long-run performance advantage over incumbent-financed companies; (iii) mitigates the stock market's more negative reaction to VC-backed acquisitions; and, finally, (iv) increases entrepreneurial incentives to innovate. To our best knowledge, with these insights we are the first to stress the importance of the implementation of usefulness clauses in the patent law for the mode of financing innovations and the innovation intensity in an economy. Indeed, the existing literature on the law and economics of intellectual property concentrates mainly on the other two requirements for an innovation to be patentable: novelty and non-obviousness[4].

In our model, there is an entrepreneur possessing an early-stage innovation that needs development to be commercially viable. The entrepreneur cannot personally develop the innovation but can sell it to an incumbent or, alternatively, seek support from a VC. The innovation can have high wealth-creating capacity; in this case investment in its development increases an acquiring firm's product-market profit and decreases profits of non-acquiring rivals. It can have low wealth-creating capacity; in this case its development has no effect on product-market profits.

Given the considerable ex-ante uncertainty about the wealth-creating capacity of newly created entrepreneurial ventures (Amit et al., 1990), both VCs and incumbents need to assess the venture's wealth-creating capacity before backing or acquiring it. In our model, VCs and incumbents differ in the precision of that assessment. This disparity could have its origin in a varying precision of information they possess regarding the early-stage innovation: Entrepreneurs could optimally disclose different amounts of information to VCs and incumbents. For example, incumbents are more likely to have the know-how to develop innovations without the entrepreneurs than VCs. Entrepreneurs could therefore fear expropriation of their typically unprotected early-stage innovations

[3]Patent law around the world requires for an innovation to be patentable that it is novel, non-obvious, and useful. An innovation fulfills the usefulness criterion if it is likely to be industrially applicable.

[4]For recent reviews of this literature, see Menell and Scotchmer, 2007, and Denicolò, 2008.

by incumbents and reveal less information to them than to VCs.[5] The disparity could also originate in diverging capabilities to process the available information: Contrary to incumbents, VCs typically have experience with a variety of ideas and markets.[6]

After an early-stage acquisition by an incumbent or the founding of a VC-backed company, the respective investor develops the innovation. The extent of their investment in development determines their patenting intensity, which VCs can use as a public signal of their venture's wealth-creating capacity before they exit. In the subsequent exit phase, after investment and patenting, incumbents bid for the acquisition of the VC-backed companies.[7]

We show that as long as it is more difficult to patent innovations with low than it is to patent those with high wealth-creating capacity, there exists a separating perfect Bayesian equilibrium in which VCs find it profitable to use patenting as a signal of their innovations' types to potential acquirers. In this equilibrium, VCs choose a level of patenting (and investment) above the one that incumbents would choose. There are two reasons for that. First, VCs exit the developed innovation. Hence, when they choose their investment level, they take into account both its positive effect on the acquiring incumbent's profit and its negative effect of the non-acquirers' profits due to their investment. Incumbents would only take into account the positive effect on their own profit. Second, if it is not sufficiently more difficult to patent innovations with low wealth-creating potential than it is to patent those with high potential, we show that the need to signal their innovation's type forces VCs to develop and patent even beyond the level that maximizes the late-stage acquisition price net of development costs. We then show that the VCs' patenting level leads to lower aggregate product-market profits net of the development costs than the patenting level that incumbents would be chose.

As the VCs' over-patenting inflates their late-stage acquisition price, we show that,

[5]For an analysis of contracting issues between informed innovators and developers exerting profit-increasing effort, see also Martimort et al., 2010.

[6]Similarly to patent officers, who have recently been documented to learn to judge the importance of innovations during an innovation cycle (Régibeau and Rockett, 2010), repeated exposure to various innovations could also give VCs a competitive edge in their judgments.

[7]This does not preclude exit via initial public offering (IPO) as long as incumbents are able to compete for the acquisition of VC-backed entrepreneurial companies before or during the IPO.

as long as the VCs' advantage in assessing entrepreneurial ventures is not too large, incumbents are better off preempting a VC by acquiring the entrepreneurial innovation early. Consequently, such early acquisitions are more likely in cases in which (i) VCs are not sufficiently more efficient than incumbents in selecting entrepreneurial innovations; (ii) innovations have a high average ex-ante potential; and (iii) it is relatively easy to patent innovations with low wealth-creating capacity.

We also show that unless it is very easy to patent innovations with low wealth-creating potential, the inflated late-stage acquisition price increases the expected payoff entrepreneurs receive from creating early-stage innovations: Entrepreneurs benefit from the presence of VCs even if an incumbent preemptively acquires their innovation.

Our model explains two apparent contradictions from the recent empirical evidence about the impact of venture capitalists on firm performance and on innovation. First, in a study on the impact of venture capital activity on several measures of innovation, Ueda and Hirukawa (2008) confirm Kortum and Lerner's (2000) earlier finding that higher venture capital activity in a given industry leads to a higher patent count. However, they also find that venture capital activity does not have an impact on total factor productivity growth. Second, Gompers and Xuan (2008) find that the stock market tends to react more negatively to announcements of acquisitions of venture capital-backed companies than to those of other private acquisitions. However, they also find that in the long run venture capital-backed acquisitions have superior operating performance.

Finally, casual observation seems to suggest that our model's implications of implementing usefulness clauses hold. This clause appears to be more stringent under a common law system, in which applicants are responsible for submitting any further evidence the patent office would need for their decision, whereas under a civil law system, this burden lies with the patent office.[8] The evidence required under the U.S. patent law in particular includes prototypes. Because prototypes increase the patent offices' information about an innovation, requiring to submit a prototype with an application for a patent presumably makes it easier for the patent office to implement stricter usefulness

[8]Under both systems, however, the same doctrine of patentable subject matter applies, ruling out the patentability of abstract concepts, such as mathematical formulas (see Chiou, 2010).

clauses than not requiring a prototype, as under European patent law. As a consequence, our model would imply more venture capital activity in the U.S. than in the E.U., which we indeed observe.[9]

1.1 Related literature

In the literature that describes their role in the innovation process, venture capitalists have been identified to be good at solving moral hazard problems (Kaplan and Strömberg, 2001; Casamatta, 2003; Schmidt, 2003; Inderst and Mueller, 2004; Keuschnigg and Nielsen, 2004; Repullo and Suarez, 2004; Hellmann, 2006), to provide managerial value added (Kanniainen and Keuschnigg, 2003; Hochberg et al., 2007; Inderst and Müller, 2009), as well as to exploit strategic product-market effects (Norbäck and Persson, 2009). We add to that literature by examining how their ability to judge an innovations' quality determines the ownership, development patterns, and the economic impact of innovations; as well as long-term firm performance. By focussing on implications of the VCs' ability to select good ideas, we also relate to recent theoretical papers that study the pre-investment selection and venture contracting process (Keuschnigg and Nielsen, 2007; Casamatta and Haritchabalet, 2007; Cestone et al., 2007; Cumming and Johan, 2008; Martimort et al., 2010). We add to this literature by focussing on the post-selection involvement of VCs characterized by signaling and oligopolistic effects.

By explaining the role hidden information about the quality of entrepreneurial ventures plays in determining the mode of financing for an innovation, we contribute to the literature regarding how different institutional settings, such as the presence of a venture capital or angel market and features of the law governing the protection of intellectual property rights, affect incentives for entrepreneurs to create and to develop innovations in an oligopolistic environment.[10]

Our paper also relates to the literature that studies how product-market effects influence the pattern of VC and incumbent financed development of innovations (Hellmann, 2002; Cassiman and Ueda, 2006) and to the literature that shows empirically that early

[9] We are grateful to Pedro Gomis Porqueras for pointing this out to us.

[10] See Acs and Audretsch (2005) and Bianchi and Henrekson (2005) for an overview.

sales or licensing are more likely when property rights are more secure (Anton and Yao, 1994; Gans and Stern, 2000; Gans and Stern, 2003). Our contribution to this literature is to allow for signaling as well as for competition for the acquisition of an innovation among oligopolistic firms. This contribution enables us to characterize in a theoretical model who develops innovations and to which extent as a function of the innovations' properties and the patent law; as well as to show how this affects stock market reactions to, and long-run performance of, private acquisitions.

To this end, we characterize a separating equilibrium, in which VCs use patents to signal their wealth-creating capacity to potential acquirers. This equilibrium is consistent with evidence that acquirers of venture capital-backed companies do not suffer any adverse selection problem (Gompers and Xuan, 2008). It is also consistent with empirical findings that firms in high-tech industries use technology proxies, such as the number of R&D personnel or patents, to signal the value of their firms to investors (Megginson et al., 2001).

A crucial feature of the models in the signaling literature,[11] which we share, is that a seller of a good uses some device to signal the quality of the good. Contrary to a large part of that literature, in our model the signal is productive as it affects the productivity of the asset (good) sold post-signaling in the ensuing product-market interaction[12]. Moreover, we add to the signaling literature by endogenously determining whether the ability to signal will be used in equilibrium. Because the signal is productive, in order to exist in equilibrium, the senders (venture capitalists) must be sufficiently more efficient in the selection of early-stage entrepreneurial ventures than the receivers (incumbents); otherwise, the receivers will block the signaling through a preemptive acquisition of the early stage innovation.

Besides reconciling Gompers and Xuan's (2008) and Ueda and Hirukawa's (2008) apparently contradicting findings, we relate to the empirical literature on the impact of venture capitalists on firm performance and innovation. The general finding in this

[11] See, for instance, Riley (2001) for an overview.

[12] An exemption is Ben-Shahar (2004) who allows for productive signaling in a real estate setting. However, in that paper, no product market effects are present, and no preemptive acquisitions are possible, both of which are crucial to our results.

literature is that venture capital is positively related to innovation (see, e.g., Hellmann and Puri, 2000; Kortum and Lerner, 2000; Okamuro and Zhang, 2006). Our contribution is to explain the impact of venture capital financing on research and development as a function of the venture capitalists' ability to assess entrepreneurial ventures and to signal their assessment to potential acquirers. In providing this explanation, we link early-stage financing by venture capitalists and its economic impact to a so-far understudied property of the patent law: the implementation of *usefulness clauses* (in the U.S. patent law) or *likely industrial application clauses* (in the European patent law).

The condition for the existence of venture capitalists in equilibrium is that their assessment of entrepreneurial innovations needs to be more precise than the incumbents' assessment. This existence condition is consistent with empirical evidence. For example, Hellmann and Puri (2000) or Engel and Keilbach (2007) show that venture capitalists have such an advantage. Shane and Cable (2002) find that being part of entrepreneurial networks gives venture capitalists an advantage over incumbents in their ability to select good entrepreneurial innovations. Gans et al. (2008) find evidence that imperfectly protected intellectual property rights matter for entrepreneurs' choice of how to commercialize innovations. Their empirical evidence suggests that the lack of intellectual property rights protection for early-stage innovations could indeed be a reason for venture capitalists to have an advantage in accessing the information needed to properly assess the wealth-creating capacity of early-stage innovations.

2 The model

Consider a model with five stages. In stage 0, the *research stage*, an entrepreneur invests in the creation of an early-stage innovation. We consider two types of early-stage innovations, denoted by $\theta \in \{g, b\}$; those with high wealth-creating capacity, which we call *good* innovations and denote by $\theta = g$; and those with low wealth-creating capacity, which we call *bad* innovations and denote by $\theta = b$. Whether the innovation is good or bad is not verifiable.

The early-stage innovation requires costly additional development for commercial use.

The entrepreneur lacks the financial means to develop the innovation herself. Instead, in stage 1, the *early-acquisition stage*, the entrepreneur can either sell the innovation to one of I ex-ante symmetric oligopolistic incumbents, $i = 1, 2, \ldots, I$, or alternatively seek support from one of J symmetric venture capitalists, $j = 1, 2, \ldots, J$. We denote the set of potential incumbents by $\mathcal{I}$ and that of the potential VCs with $\mathcal{J}$. We model the sale of the early-stage innovation as a first-price sealed-bid auction. We assume that potential investors do not observe each others' offers in this process and that the entrepreneur cannot credibly communicate a received offer to other potential investors. We denote the price paid in this auction by P_1.

Prior to making an offer for the early-stage entrepreneurial venture, the potential investors receive private, non-contractible signals regarding the venture's wealth-creating capacity, either good or bad. While we assume the signal VCs receive to be perfect, the signal incumbents receive is correct only with probability $a \in \left[\frac{1}{2}, 1\right]$. For simplicity, we assume all incumbents to receive the same imperfect signal. Denote their signal by $s \in \{g, b\}$. Let $q \in \,]0, 1[$ be the prior probability that an innovation is good. Define λ^s to be the probability incumbents assign to the event that the innovation is good after receiving signal s. Then $\lambda^g := \frac{aq}{aq+(1-a)(1-q)}$, whereas $\lambda^b := \frac{(1-a)q}{(1-a)q+a(1-q)}$. It is straightforward to show $\lambda^b < q < \lambda^g$.[13]

In stage 2, the *investment and patenting stage*, either a VC or an incumbent finances the innovation's development. For simplicity, we assume that after it acquired the early-stage innovation but before it invests in its development, the acquiring incumbent can inform itself perfectly regarding the innovation's type.[14] The investment in development enables both VCs and incumbents to file for patents for their innovations. We assume that a higher patenting intensity requires a higher investment, and therefore leads to higher costs of development. We define this cost as $C(f, \theta)$, where f is the chosen patenting

[13]Our results do not depend on the assumption that VCs are better informed. In fact, as we will show, VCs must be *sufficiently* better informed to be active in equilibrium. Thus, not assuming that they are better informed would not alter our insights. It would, however, complicate our analysis. Likewise, if we assumed both VCs and incumbents to be not perfectly informed, we would expect the analysis, e.g., the auction game in stage 1, to become much more involved, without changing our main results.

[14]Our results would also hold if incumbents cannot infer the innovation's wealth-creating capacity before they invest into its development.

intensity. The patenting intensity represents any observable measure of the product space protected by patents of the firm, such as the breadth of a single patent or simply the number of patents obtained which are close to the entrepreneurial innovation. Denoting $C_f(f,\theta)$ and $C_{ff}(f,\theta)$ the first and second derivative of C with respect to f, respectively, we assume:

Assumption 1 $C(0,\theta)=0$, $C_f(f,b)>C_f(f,g)>0$, *and* $C_{ff}(f,\theta)>0$.

The patenting cost function C is increasing and convex in f and, for a given patenting intensity, it is larger for a bad innovation than for a good one. [15]

In stage 3, the *late-acquisition stage*, upon development, the VC exits by selling the developed innovation to one of the incumbents. We model this sale as a first-price sealed-bid auction. We denote the price paid in this auction by P_3.

In stage 4, the *product-market competition stage*, the incumbent oligopolistic firms interact in the product-market, choosing actions (such as, e.g., price, quantity produced, marketing effort), which in equilibrium are a function of f and θ. We denote the respective equilibrium product-market profits of an acquirer and of non-acquirers with $\Pi_A(f,\theta)$ and $\Pi_N(f,\theta)$ and assume them to have the following properties.

Assumption 2 *Equilibrium product-market profits* $\Pi_A(f,\theta)$ *and* $\Pi_N(f,\theta)$ *satisfy*

1. $\Pi_A(0,g)=\Pi_N(0,g)=\Pi_A(f,b)=\Pi_N(f,b)$;
2. $\frac{d\Pi_A(f,g)}{df}>0$, $\frac{d\Pi_N(f,g)}{df}<0$, $\frac{d\Pi_A(f,b)}{df}=\frac{d\Pi_N(f,b)}{df}=0$;
3. $\frac{d^2\Pi_A(f,g)}{df^2}\leq 0$, $\frac{d^2\Pi_N(f,g)}{df^2}\geq 0$.

Assumption 2 says that a good innovation that does not receive investment in its development, and hence is not patented, and bad innovations (irrespective of the investment and patenting level) do not affect the equilibrium product-market profits; that the equilibrium product-market profit of the acquirer of a good innovation is strictly increasing and the rivals' equilibrium product-market profits are strictly decreasing in the

[15] Note that, even though bad innovations have only a low wealth-creating capacity, there is no reason why one could not, theoretically, apply for patents on these innovations.

patenting intensity; and that the impact of the patenting intensity onto the equilibrium product-market profits is decreasing in the patenting intensity.[16] [17] [18]

3 Analysis

We solve the model backwards. Using the properties of the product-market profits just introduced, we start the analysis with the late-acquisition stage. If a VC backs the entrepreneurial company, we solve for a separating perfect Bayesian equilibrium (PBE) in which the VC signals the nature of the innovation through its patenting choice.

3.1 Late-acquisition stage

Consider the late acquisition stage, which is reached only in case a VC backs the entrepreneurial company. In the separating PBE, the bidding incumbents correctly infer an innovation's type from the venture capital-backed company's patenting intensity. Thus, it is appropriate to model the acquisition process in stage 3 as a perfect information first-price sealed-bid auction with I incumbents as bidders and the VC as the seller. As in any such auction, the winning bid equals the second highest bidder's valuation and, as prior to an acquisition incumbents are symmetric, in our model this bid equals the highest bidder's valuation. Denoting with f_j^b and f_j^g the venture capital-backed company's equilibrium level of patenting for a bad and a good innovation and with $P_3(f_j)$

[16]We are not interested in the product-market interaction per se. Hence, we do not solve directly for this stage in the analysis but make assumptions on its consequences on the equilibrium product-market profits, $\frac{d\Pi_A(f,\theta)}{df}$ and $\frac{d\Pi_N(f,\theta)}{df}$. Given the patenting intensity corresponds to a costly investment, our assumptions hold in a large class of oligopoly models, which comprises, among many others, the model of Farrell and Shapiro (1990) or Cournot models with linear demand, in which R&D leads to a reduction in unit production cost or an improvement in perceived product-quality.

[17]That investment in and patenting of bad innovations does not affect product-market profits is an innocent normalization as our main results hold as long as the value created by investment in and patenting of bad innovations is lower than that created by investment in and patenting of good ones. Note also that we assume, in their product-market interaction, acquirers and non-acquirers know the nature of the innovation. We could alternatively assume that the competitors learn the innovation's type in repeated oligopoly interaction. This alternative assumption would complicate our analysis without altering our main insights.

[18]Note that most of our results would hold if, instead of assuming that the acquirer's profit from a good innovation increases in the patenting intensity and a non-acquirer's profit decreases ($\frac{d\Pi_A(f,g)}{df} > 0$ and $\frac{d\Pi_N(f,g)}{df} < 0$), we only assumed that the difference between an acquirer's and a non-aquirer's profit increases in the patenting intensity ($\frac{d\Pi_A(f,g)}{df} - \frac{d\Pi_N(f,g)}{df} > 0$). In section 5, we discuss in detail, which of our results hold under this alternative assumption and which do not hold any longer.

the equilibrium acquisition price of the developed innovation in stage 3 as a function of any patenting choice of the VC-backed company, we can state without proof:

Lemma 1 *In any separating perfect Bayesian equilibrium, good developed innovations receive an equilibrium price equal to the incumbents' valuation of the developed good innovation, i.e.,* $P_3\left(f_j^g\right) = \Pi_A\left(f_j^g, g\right) - \Pi_N\left(f_j^g, g\right)$*; and bad innovations receive an equilibrium price equal to zero, i.e.,* $P_3\left(f_j^b\right) = \Pi_A\left(f_j^b, b\right) - \Pi_N\left(f_j^b, b\right) = 0$.

3.2 Patenting and investment stage

In this subsection, we solve for both the early-stage acquiring incumbent's and the venture capital-backed companies' optimal patenting intensities and then compare them with each other.

Incumbent's investment and patenting After an early-stage acquisition the acquiring incumbent has been assumed to be able to inform itself perfectly about the innovation's nature. Therefore, as patenting of bad innovations does not affect product market profits, $f_i^b = 0$. If the innovation is good, the incumbent chooses an optimal patenting intensity

$$f_i^g = \arg\max_f \left[\Pi_A\left(f, g\right) - C\left(f, g\right)\right]. \tag{1}$$

Venture capital-backed companies' investment and patenting VCs choose their patenting level f_j such as to maximize the anticipated equilibrium sale price, $P_3\left(f_j\right)$, net of the cost of investment. As we are solving for a separating PBE, we determine an optimal patenting choice for each type of innovation.

Consider the equilibrium patenting level for a venture capital-backed company owning a bad innovation. In any separating PBE the venture capital-backed company receives a sale price of zero, $P_3\left(f_j^b\right) = 0$ (Lemma 1). Therefore, in any separating PBE, there is no reason for venture capital-backed companies to apply for any patents for bad innovations and $f_j^b = 0$. In equilibrium, venture capital-backed companies do not develop the innovation and, thus, do not patent innovations with low wealth-creating capacity.

Now consider the equilibrium patenting level for a venture capital-backed company possessing a good innovation. Assumptions 1 and 2 imply that there exist equilibrium patenting levels for venture capital-backed companies with good innovations, which venture capital-backed companies possessing bad innovations would not find profitable to choose. These patenting levels fulfill the incentive compatibility constraint

$$\Pi_A(f_j, g) - \Pi_N(f_j, g) - C(f_j, b) \leq 0. \tag{2}$$

Denote the patenting level for a good innovation, for which the incentive compatibility constraint holds with equality, by f_j^c. The superscript c signifies that the venture capital-backed company chooses this level if it is *constrained* in its patenting choice by the need to signal its innovation's type. As any patenting level greater than or equal to f_j^c is incentive compatible and as the late-stage acquisition price for a venture capital-backed company with a good innovation, $P_3\left(f_j^g\right)$, is an increasing function of the company's patenting level, in equilibrium the incentive compatibility constraint need not bind. If it does not, the venture capital-backed company chooses its *unconstrained* optimal patenting level,

$$f_j^u := \arg\max_{f_j}[\Pi_A(f_j, g) - \Pi_N(f_j, g) - C(f_j, g)]. \tag{3}$$

Thus, the optimal patenting level of venture capital-backed companies is the greater one of f_j^c and f_j^u, i.e., $f_j^g = \max\left\{f_j^c, f_j^u\right\}$.

Holding everything else constant, f_j^c is larger if it is easy than if it is hard to patent bad innovations. Therefore, it is likely that a venture capital-backed company is constrained in its patenting choice and has to patent at an intensity that surpasses its unconstrained optimum if it is not sufficiently more difficult to patent innovations with a low wealth-creating capacity than it is to patent those with a high wealth-creating capacity. Proposition 1 summarizes these results.

Proposition 1 *In the separating PBE, venture capital-backed companies*

1. *do not invest in innovations with low wealth-creating capacity;*

2. *invest in innovations with high wealth-creating capacity*

(a) as they would in the absence of information asymmetries as long as it is sufficiently difficult to patent innovations with low wealth-creating capacity; and

(b) beyond the level they would choose in the absence of information asymmetries if it is not sufficiently difficult to patent innovations with low wealth-creating capacity.

Figures 1 and 2 illustrate how the VCs chosen patenting intensity depends on the implementation of usefulness clauses in the patent law: If they are strict, then patenting bad innovations is sufficiently more costly than patenting good innovations and the VCs' incentive compatibility constraint is not binding. In this case, VCs invest such that their patenting intensity is $f_j^u > f_j^c$. If they are lax, then patenting bad innovations is not sufficiently more costly than patenting good innovations and the VCs' incentive compatibility constraint is binding. In this case, VCs have to invest beyond the value that would maximize their profits absent information asymmetries and their patenting intensity is $f_j^c > f_j^u$.

[Insert figures 1 and 2 here.]

Comparison of patenting levels of incumbents and venture capital-backed companies In the separating PBE, both VCs and incumbents take into account that the extent of their patenting affects the product-market profits of the acquirer. However, VCs also take into account that it impacts negatively on the non-acquirers' product-market profits. Therefore, the patenting level chosen by a VC that is not constrained by the need to signal, f_j^u, is larger than that chosen by an incumbent, f_i^g. Furthermore, if the unconstrained optimal patenting choice is not sufficient to signal an entrepreneurial innovation with a high wealth-creating capacity, the VCs have to invest such that they can patent at an even higher intensity, f_j^c. Therefore, we can state the following:

Proposition 2 *The optimal patenting intensity of VCs exceeds the optimal patenting intensity of acquiring incumbents with comparable innovations.*

Comparison of industry profits from developing early-stage innovations Industry profits net of development costs, $\Pi_{IND}(f,g)$, are

$$\Pi_{IND}(f,g) = \Pi_A(f,g) + (I-1)\Pi_N(f,g) - C(f,g).$$

Compare the industry profits net of development costs in case of VC-backed development of a good innovation with those in case of incumbent-financed development. First note that f_i^g maximizes $\Pi_A(f,g) - C(f,g)$. Second note that as incumbents patent less than VC-backed companies, $f_i^g < f_j^g$, and as the non-acquirers' product-market profits decrease in the amount of development of a good innovation, $\frac{d\Pi_N(f,g)}{df} < 0$, also the profits of non-acquirers are larger in case of incumbent-financed development than in case of VC-financed development. Now consider bad innovations. Bad innovations do not affect product-market profits and are not developed in equilibrium. Thus, they do not impact on industry profits. Thus we can state the following.

Proposition 3 *For a good innovation, the industry profits net of development costs in case of incumbent-financed development are larger than the ones in case of VC-backed development. There is no difference for bad innovations.*

3.3 Early-acquisition stage

The first step in determining equilibrium ownership and acquisition price of early-stage entrepreneurial companies is to derive the stage 1 valuations. We denote these stage 1 valuations by v. For VCs, they depend on the innovation's type, θ, and for incumbents on their stage 1 signal, s.

Incumbents' stage 1 valuations Incumbents have to consider two alternative scenarios when they bid for an early-stage innovation. First, the innovation could be obtained and developed by a competitor in the product market. Second, the innovation's development could be backed by a VC, which would over-invest and over-patent before exiting.

Denote by $v_{ii}(s)$ the incumbents' expected value of acquiring the early-stage innovation when it would otherwise be obtained and developed by a competitor in the product market, as a function of their stage 1 signal. This valuation is equal to the difference in the expected net profit of the acquirer and those of a non-acquirer:

$$v_{ii}(s) = \lambda^s \left[\Pi_A\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right] + (1-\lambda^s)\,\Pi_A\left(f_i^b, b\right) - \lambda^s \Pi_N\left(f_i^g, g\right) - (1-\lambda^s)\,\Pi_N\left(f_i^b, b\right), \tag{4}$$

or simplified

$$v_{ii}(s) = \lambda^s \left[\Pi_A\left(f_i^g, g\right) - \Pi_N\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right]. \tag{5}$$

Denote by $v_{ij}(s)$ the incumbents' expected value of obtaining the innovation when it would otherwise be obtained, over-developed, and sold by a VC, as a function of the incumbents' stage 1 signal. It has the same structure as $v_{ii}(s)$ with one exception. The profit of being a non-acquirer is now function of f_j^g.

$$v_{ij}(s) = \lambda^s \left[\Pi_A\left(f_i^g, g\right) - \Pi_N\left(f_j^g, g\right) - C\left(f_i^g, g\right)\right]. \tag{6}$$

VCs' stage 1 valuations Consider first a VC's valuation for a bad early-stage innovation, denoted by $v_j(b)$. As late acquisition price for a company with a bad innovation is zero, $P_3\left(f_j^b\right) = 0$, VCs have a valuation of zero, $v_j(b) = 0$.

Now, consider a VC's valuation for a good early-stage innovation, denoted by $v_j(g)$. It corresponds to the sale price of the developed innovation in stage 3, net of the investment costs:

$$v_j(g) = \Pi_A\left(f_j^g, g\right) - \Pi_N\left(f_j^g, g\right) - C\left(f_j^g, g\right). \tag{7}$$

We denote the VCs' valuation for a good innovation if the VC is constrained and unconstrained in its choice of f in stage 2 by $v_j^c(g)$ and $v_j^u(g)$.

Equilibrium ownership and offers Before determining the equilibrium ownership and the equilibrium sale price of the early-stage entrepreneurial company, denoted P_1^*, we compare the valuations derived. The following Lemma summarizes the comparisons between $v_j(g)$, $v_{ii}(s)$, and $v_{ij}(s)$.

Lemma 2 *1. For all* $\lambda^s \in]0,1]$, $v_{ii}(s) < v_{ij}(s)$.

2. *There exists a* λ^p *such that for* $\lambda^s < \lambda^p$, $v_{ij}(s) < v_j(g)$ *and for* $\lambda^s > \lambda^p$, $v_{ij}(s) > v_j(g)$.

3. *For all* $\lambda^s \in]0,1]$, $v_j^u(g) > v_{ii}(s)$. *For* $C_f(f,g)$ *and* $C_f(f,b)$ *sufficiently similar, there exists a* λ^{ii} *s.t. for* $\lambda^s < \lambda^{ii}$, $v_j^c(g) > v_{ii}(s)$ *and for* $\lambda^s > \lambda^{ii}$, $v_j^c(g) < v_{ii}(s)$.

Proof. See Appendix A. ■

As VCs are assumed to be symmetric, they offer their valuation $v_j(g)$ or $v_j(b) = 0$.

If $\lambda^s < \lambda^p$, the VCs' offer for good innovations is higher than the incumbents' valuation, v_{ij}^s. Thus, in this interval, incumbents are not able to appropriate good innovations. If they offer a positive amount in spite of that, incumbents would only appropriate bad innovations. Therefore, they maximize their expected payoff by offering zero and the winning offer is $P_1^* = v_j^g$ for good innovations and $P_1^* = 0$ for bad ones.

If $\lambda^p < \lambda^s$, the VCs' bid for good innovations is lower than the incumbents' valuation, $v_{ij}(s)$. Thus, an incumbent makes the highest offer and the superscript p in λ^p, anticipates that for $\lambda^s > \lambda^p$ incumbents *preemptively acquire* early-stage innovations. Note that, even though incumbents are assumed to be symmetric, they do not offer their valuation $v_{ij}(s)$. Once one incumbent offers more than the VCs would (by an ϵ), the threat of having to acquire an over-developed innovation is gone and the other incumbents only have a valuation of $v_{ii}(s)$. Note furthermore that, if incumbents offer less than $v_j(g)$, they only acquire bad innovations, which cannot be optimal. Thus the winning offer is either $v_j(g)$ or $v_{ii}(s)$. If $\lambda^p < \lambda^s < \lambda^{ii}$, the winning offer (and acquisition price) is $P_1^* = v_j(g)$, while if $\lambda^p < \lambda^{ii} < \lambda^s$, it is $P_1^* = v_{ii}(s)$.

Proposition 4 summarizes these results.

Proposition 4 *1. For* $\lambda^s < \lambda^p$, *(i) good innovations are developed by VCs, who paid a price* $P_1^* = v_j(g)$*; and (ii) bad innovations do not receive financing by either VCs or incumbents.*

2. *For* $\lambda^p < \lambda^s < \lambda^{ii}$, *(i) good innovations are preemptively acquired and developed by*

an incumbent who paid a price $P_1^* = v_j(g)$; and (ii) bad innovations are preemptively acquired by an incumbent who paid a price $P_1^* = v_j(g)$, but they are not developed;

3. *For $\lambda^{ii} < \lambda^s$, (i) good innovations are preemptively acquired and developed by an incumbent who paid a price $P_1^* = v_{ii}(s)$; and (ii) bad innovations are preemptively acquired by an incumbent who paid a price $P_1^* = v_{ii}(s)$, but they are not developed.*

Proof. See Appendix B. ■

As long as λ^s is sufficiently high, incumbents acquire early-stage innovations to preempt, for them, excessive investments in development and the resulting excessive patenting that would otherwise be undertaken by a VC. With such a preemptive acquisition, they avoid either having to pay an excessive late-stage acquisition price if they acquire the developed innovation from a VC; or having to face a much more efficient competitor if another incumbent acquires the developed innovation from a VC.

Characterization of the results in terms of a and q Assume that the prior probability of success, q, is sufficiently low. In particular, let it be such that the incumbents' valuation without a signal (or with an uninformative signal) is lower than the VCs' valuation for a good project.[19]

Under this (reasonable) assumption, incumbents preemptively acquire early-stage entrepreneurial ventures if and only if they received a good signal ($s = g$) *and* they are sufficiently precise in their assessment of these ventures (a large). They offer zero for the ventures if their assessment is too imprecise (a small) or if they received a bad signal ($s = b$), or both.

As shown in Proposition 4, if it is sufficiently more difficult to patent innovations with low than those with high wealth-creating capacity, the early-stage acquisition price equals the VCs' valuation for a good innovation, $P_1^* = v_j^u(g)$, irrespective of whether a VC or an incumbent finances the entrepreneurial venture. This price is, hence, also independent of the incumbents' precision in their assessment of early-stage ventures.

[19] We provide a full characterization of the results in terms of a and q – relaxing this assumption – in Appendix C.

As also shown in Proposition 4, if it is *not* sufficiently more difficult to patent innovations with low than those with high wealth-creating capacity, the early-stage acquisition price equals the VCs' valuation for a good innovation, $P_1^* = v_j^u(g)$, as long as the posterior probability of success (after the incumbents' signal) is sufficiently low. It equals the incumbents' valuation for entrepreneurial ventures with a good signal in the absence of VCs, $P_1^* = v_{ii}^c(g)$ for a sufficiently high posterior probability of success (after the incumbents' signal). Therefore, if it is easy to patent bad innovations, the price paid to the entrepreneurs in the early-acquisition stage depends on the precision of the incumbents' assessment. For very precise assessments, it equals the price that would have been paid by incumbents in the absence of VCs, it is larger otherwise.

3.4 Research stage

The VCs' existence has implications for the rewards entrepreneurs receive for their early-stage innovations. To see these implications, we derive the equilibrium properties of a benchmark model without VCs.[20]

The model corresponds to the one introduced above net of the presence of VCs. Consequently, the analysis for the investment stage, given that an incumbent makes an early acquisition, still applies. However, in the absence of VCs, entrepreneurs can only turn to incumbents for the development of their early-stage innovations. Thus, in the acquisition game in period 1, only incumbents make offers. As they only make offers to avoid the early acquisition by a rival, they only have valuation $v_{ii}(s)$. This leads to Proposition 5.

Proposition 5 *In the exogenous absence of VCs, all innovations are acquired by an incumbent that paid a price* $P_1^* = v_{ii}(s)$*; good innovations receive investment leading to a patenting level of* f_i^g*, and bad innovations are not developed.*

Thus the acquisition price is lower than in the presence of VCs since incumbents do not need to preempt the VCs' over-patenting.

[20]Indeed, in some countries and in some industries, venture capital is not present due to restrictions outside of our model.

Compare this result with the one obtained in the model with VCs. If $\lambda^s < \lambda^p$, VCs offer $v_j(g)$ for good and zero for bad innovations. Incumbents always offer zero. Consequently, the entrepreneur has a payoff of $v_j(g)$ for good and zero for bad innovations. Therefore, the expected (gross) payoff for early-stage innovations is $\lambda^s v_j(g)$, which is greater than $v_{ii}(s)$. If $\lambda^p < \lambda^s < \lambda^{ii}$, the winning incumbent offers $v_j(g)$, which is also greater than $v_{ii}(s)$, and the expected (gross) payoff for the entrepreneur is $v_j(g)$. If $\lambda^{ii} < \lambda^s$, the incumbents offer $v_{ii}(s)$, which is also the entrepreneur's expected (gross) payoff. Therefore, as long as $\lambda^s < \lambda^{ii}$, the existence of VCs increases the winning offer and the entrepreneurs' gross payoff from early-stage innovation, even if incumbents preemptively acquire their company.

Proposition 6 *The existence of VCs increases the incentives for entrepreneurs to engage in early-stage innovation for $\lambda^s < \lambda^{ii}$ and does not change them otherwise.*

3.5 The effect of usefulness clauses

In this subsection, we first highlight the empirical implications of our model for the mode of development of innovations, the patenting and investment intensity, total factor and labor productivity growth, and entrepreneurial incentives. We then show how these depend on the implementation of usefulness requirements in the patentability of innovations.

Venture capital activity We first turn to the circumstances under which VCs finance entrepreneurial companies. The role VCs play in our model is that of informed intermediaries. They contribute their superior precision in the assessment of early-stage entrepreneurial ventures and transmit their assessment to the public by means of their chosen patenting intensity – if they finance an innovation. The following implication summarizes the consequences thereof:

Implication 1 *VCs are active in industries in which there is a low ex-ante probability that entrepreneurial innovations have high wealth-creating capacity, in which they have a large advantage over incumbents in the assessment of entrepreneurial innovations, and in which it is sufficiently more difficult to patent bad than good developed innovations.*

Patenting effect and investment effect In our model, VCs signal their innovation's type by means of patenting. To do so, they strategically over-patent and over-invest as compared to incumbents. Consequently, we can state the following implication:

Implication 2 *Companies financed by VCs patent and invest more than those financed by incumbents with comparable innovations.*

Indeed, venture capital intensive industries have been found to exhibit higher patent counts (Kortum and Lerner, 2000, Ueda and Hirukawa, 2008).

Venture capital-backed companies have also been found to invest more in R&D (Okamuro and Zhang, 2006, Puri and Zarutskie, 2007). While Inderst and Mueller (2009) find that venture capital-backed entrepreneurial companies invest more if they are in competition with other entrepreneurial companies innovating in the same niche, we base this insight on competition among potential acquirers in the exit stage and the transmission of the VCs' superior information. Thus, while their model is a good description of the role of early-stage financing in new industries, our model is well-suited for explaining its role as invention suppliers in industries with incumbents.

Productivity effect The VCs' higher incentives to patent and invest affects their productivity in a surprising way. In Proposition 3, we have shown that industry profits net of development costs of a given good entrepreneurial innovation are larger if the innovation is developed by an incumbent than if it is developed by a VC-backed company, since VCs strategically over-invest. This over-investment impacts negatively on total factor productivity growth in industries with high as compared to industries with low venture capital activity.

In Proposition 6 we have shown that venture capital activity increases entrepreneurial incentives to engage in early-stage innovation. These higher incentives increase the number of innovations and raise total factor productivity growth in industries with high as compared to industries with low venture capital activity.

Finally, as patents obtained are based on capital investments, it is likely that they lead to higher labor productivity. As a consequence, we have the following implication:

Implication 3 *Venture capital activity in an industry (country) has (i) an ambiguous effect on total factor productivity growth, and (ii) a positive effect on labor productivity growth.*

Indeed, Ueda and Hirukawa (2008) presents empirical evidence for both parts of this prediction of our model, leading to an apparent contradiction of their finding that venture capital activity does not seem to impact on total factor productivity growth with their observation that venture capital activity has a positive impact on industry patent count and, therefore, on innovation.

Venture capitalists have been theorized to solve moral hazard problems by means of superior monitoring abilities and to add value to entrepreneurial ventures, e.g., by bringing their business expertise or access to networks. Note that, keeping everything else constant, these theories necessarily imply a higher total factor productivity in venture capital-backed companies than in non-venture capital-backed ones. Thus, our model provides testable implications that *cannot be derived* from these alternative theories.

Usefulness requirements in patentability Finally, all effects mentioned so far, are functions of how difficult it is for VCs to signal their innovations' types. Their means of signaling is their patenting intensity, and it is possible to use it as a signal because it is more difficult to patent developed innovations with low than it is to patent those with high wealth-creating capacity. The patent law implements differences in the difficulty to patent innovations with high and low wealth-creating capacity by requiring usefulness of an innovation (see, e.g., Hall et al. 2005): For example, U.S. patent law requires that, to be patentable, an innovation must be useful and European patent law requires for it to be susceptible of industrial application.

We have shown that the VCs' patenting (and investment) is the higher, the more similar the difficulty to patent innovations with high and low wealth-creating capacity. As a consequence, the difficulty to patent good and bad innovations impacts on the entrepreneurial incentives to innovate and the amount of venture capital activity altogether.

Hence, the implementation of usefulness clauses has repercussions for investment, patenting, entrepreneurial incentives and venture capital activity.

Implication 4 *The implementation of usefulness clauses in the patent law decreases the VCs' investment in development of good innovations and their patenting intensity as well as the gap between their and the incumbents' investment and patenting rates; and it increases entrepreneurial incentives to innovate as well as the number of venture capital-backed entrepreneurial companies.*

4 Stock returns to announcements of entrepreneurial acquisitions

Within our model, different types of acquisitions imply different stock market reactions to their announcements, both for the acquirer and its rivals. In this section, we consider late acquisitions of VC-backed companies, late acquisitions of incumbent-financed companies that are sold for liquidity reasons, early, preemptive acquisitions in the presence of VCs, and early, preemptive acquisitions in the exogenous absence of VCs.

Stock returns to acquirers Let the announcement of acquisitions – late or early – by an incumbent be a surprise to stock market investors. Then actual stock returns[21] around the announcement date reflect the changes in the acquirer's payoff streams due to the acquisition. Denote the actual returns of the acquiring firm's stock upon the announcement of an early acquisition in the exogenous absence of VCs by R_A^e, those upon the announcement of a preemptive acquisition in the presence of VCs by R_A^p, those upon the liquidity-driven late acquisition of incumbent-financed companies by R_A^l, and those upon the announcement of a late acquisition of VC-backed companies by R_A^v. Then

[21]The stock market reaction to an event is typically measured through abnormal returns (see MacKinlay, 1997). Therefore, we need to derive differences in abnormal returns associated with early and late acquisitions. Abnormal returns reflect *actual returns* net of *normal returns*. As there is no reason why normal returns, e.g., from a constant mean returns model, to the stock of an acquirer should be different in the event of a venture capital-backed acquisition than in that of another private acquisition, we can limit ourselves to studying differences in the actual returns.

in our model,

$$R_A^e = \lambda^s \left[\Pi_A\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right] + \left(1-\lambda^s\right)\Pi_A\left(0, b\right) - \Pi_A\left(0, \theta\right) - \lambda^s \left[\Pi_A\left(f_i^g, g\right) - \Pi_N\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right], \quad (8)$$

where $\lambda^s \left[\Pi_A\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right] + \left(1-\lambda^s\right)\Pi_A\left(0, b\right)$ is the expected profit stream with the acquisition, $\Pi_A\left(0, \theta\right)$ the expected profit stream without the acquisition, and $\lambda^s[\Pi_A\left(f_i^g, g\right) - \Pi_N\left(f_i^g, g\right) - C\left(f_i^g, g\right)]$ is the acquisition price. Similarly, we have

$$R_A^p = \lambda^s \left[\Pi_A\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right] + \left(1-\lambda^s\right)\Pi_A\left(0, b\right) - \Pi_A\left(0, \theta\right) - \left[\Pi_A\left(f_j^g, g\right) - \Pi_N\left(f_j^g, g\right) - C\left(f_j^g, g\right)\right], \quad (9)$$

$$R_A^l = \Pi_A\left(f_i^g, g\right) - \Pi_A\left(0, \theta\right) - \left[\Pi_A\left(f_i^g, g\right) - \Pi_N\left(f_i^g, g\right)\right], \quad (10)$$

and

$$R_A^v = \Pi_A\left(f_j^g, g\right) - \Pi_A\left(0, \theta\right) - \left[\Pi_A\left(f_j^g, g\right) - \Pi_N\left(f_j^g, g\right)\right]. \quad (11)$$

Taking the difference between the returns to the acquirer's stock upon the announcement of an acquisition of an entrepreneurial company that was not VC-backed (early, preemptive, or liquidity-driven) and those upon the announcement of late acquisitions of VC-backed companies, we get

$$R_A^e - R_A^v = \lambda^s \Pi_N\left(f_i^g, g\right) + \left(1-\lambda^s\right)\Pi_A\left(0, b\right) - \Pi_N\left(f_j^g, g\right), \quad (12)$$

$$R_A^p - R_A^v = \lambda^s \left[\Pi_A\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right] + \left(1-\lambda^s\right)\Pi_A\left(0, b\right) - \left[\Pi_A\left(f_j^g, g\right) - C\left(f_j^g, g\right)\right], \text{ and} \quad (13)$$

$$R_A^l - R_A^v = \Pi_N\left(f_i^g, g\right) - \Pi_N\left(f_j^g, g\right). \quad (14)$$

As the incumbents' patenting intensity is smaller than the VCs', $0 < f_i^g < f_j^g$, and as the non-acquirers' profit is decreasing in the patenting intensity, $\frac{d\Pi_N(f,g)}{df} < 0$, the non-acquirers' profit in case of VC-backed development is smaller than in case of incumbent-financed development, which in turn is smaller than in case no development occurs, i.e., $\Pi_N\left(f_j^g, g\right) < \Pi_N\left(f_i^g, g\right) < \Pi_A\left(0, \theta\right)$. Thus, the difference between the abnormal returns to an announcement of an early, preemptive acquisition (in the exogenous absence of VCs) and a late acquisition of a VC-backed company, $R_A^e - R_A^v$, is positive.

Furthermore, for the same reason, $0 < f_i^g < f_j^g$, and $\frac{d\Pi_N(f,g)}{df} < 0$, also the difference between the abnormal returns to an announcement of an liquidity driven sale and a late acquisition of a VC-backed company, $R_A^l - R_A^v$, is positive.

In the presence of VCs, early, preemptive acquisitions by incumbents are observed as long as $v_{ij}(s) > v_j(g)$. In this case, λ^s is large and, therefore, also the difference between the abnormal returns to an announcement of an early, preemptive acquisition (in the presence of VCs) and a late acquisition of a VC-backed company, $R_A^p - R_A^v$, is positive (see Appendix D for a formal proof). These two results support Gompers and Xuan's (2008) empirical observation that the stock market reacts more negatively to venture capital-backed than to other private acquisitions. Thus, we can state the following:

Proposition 7 *Abnormal returns to the stock of an acquiring incumbent upon the announcement of a late acquisition of a VC-backed company are smaller (less positive/more negative) than those upon the announcement of other private acquisitions.*

Stock returns to non-acquirers Denote the returns to the stock of a non-acquiring competitor of the acquiring incumbent upon the announcement of an early acquisition in the exogenous absence of VCs by R_N^e, those upon the announcement of a preemptive acquisition in the presence of VCs by R_N^p, those upon the liquidity-driven late acquisition of incumbent-financed companies by R_N^l, those upon the announcement of a late acquisition of an incumbent-financed company by R_N^v. Then in our model,

$$R_N^e = R_N^p = \lambda^s \Pi_N(f_i^g, g) + (1 - \lambda^s)\Pi_N(0, b) - \Pi_N(0, \theta), \tag{15}$$

$$R_N^l = \Pi_N(f_i^g, g) - \Pi_N(0, \theta), \tag{16}$$

and

$$R_N^v = \Pi_N\left(f_j^g, g\right) - \Pi_N(0, \theta). \tag{17}$$

Again, taking the difference between the returns to the non-acquirer's stock upon the announcement of an acquisition of an entrepreneurial company that was not VC-backed (early, preemptive, or liquidity-driven) and those upon the announcement of late acquisitions of VC-backed companies, we get

$$R_N^e - R_N^v = R_N^p - R_N^v = \lambda^s \Pi_N \left(f_i^g, g\right) + \left(1 - \lambda^s\right) \Pi_N \left(0, b\right) - \Pi_N \left(f_j^g, g\right), \text{ and} \quad (18)$$

$$R_N^l - R_N^v = \Pi_N \left(f_i^g, g\right) - \Pi_N \left(f_j^g, g\right). \quad (19)$$

Once more, as the incumbents' patenting intensity is smaller than the VCs', $0 < f_i^g < f_j^g$, and as the non-acquirers' profit is decreasing in the patenting intensity, $\frac{d\Pi_N(f,g)}{df} < 0$, the non-acquirers' profit in case of VC-backed development is smaller than in case of incumbent-financed development, which in turn is smaller than in case no development occurs, i.e., $\Pi_N \left(f_j^g, g\right) < \Pi_N \left(f_i^g, g\right) < \Pi_A \left(0, b\right)$. Therefore, also $R_N^p - R_N^v$, $R_N^e - R_N^v$, and $R_N^l - R_N^v$ are positive. Thus, we can state the following:

Proposition 8 *Abnormal returns to the stock of a non-acquiring incumbent upon the announcement of a late acquisition of a VC-backed company are smaller (less positive/more negative) than those upon the announcement of other private acquisitions.*

Therefore, even though our model predicts superior long-run operating performance of VC-backed entrepreneurial acquisitions due to superior investment levels, it also predicts a stronger negative reaction of the stock market than to other acquisitions and gives a theoretical explanation for the evidence presented in Gompers and Xuan (2008).

Further, the implementation of usefulness clauses affects the venture capitalists' ability to signal. Therefore, it has repercussions also for the stock market's reaction to the announcement of private acquisitions as well as for the long-run performance gap of venture capital-backed and incumbent-developed entrepreneurial innovations.

Implication 5 *The implementation of usefulness clauses in the patent law decreases both the long-rung performance gap as well as the difference in the stock market's reaction to venture capital-backed and other private acquisitions.*

5 Further discussion

Equilibrium selection Signaling games often have multiple equilibria. We have chosen to solve our model for the efficient separating PBE in which either the unconstrained profit-maximizing investment, f_j^u, or the minimum necessary investment to signal, f_j^c, is chosen.

However, there also exist pooling PBEs in which VCs choose equal levels of patenting for good and bad innovations. In this case, incumbents would not learn the innovation's type and could bid in stage 3 only in expectations. As in the separating PBE, also in the pooling PBE VCs would choose the amount of patenting to maximize the expected difference between the profit of an acquirer and a non-acquiring incumbent, which would inflate the acquisition price an acquirer has to pay. In addition, they would not maximize the profits from the innovation. However, in the separating PBE, there was an off-setting effect from the transmission of the VCs' information to the potential acquirer; with the consequence that incumbents did not prefer to preemptively acquire the early-stage innovation if the information advantage of the VCs was sufficiently large. This off-setting effect does not exist in a pooling PBE. Therefore, in a pooling PBE, incumbents would *always* acquire the entrepreneurial innovation in stage 1, and VCs (and Angels) would not be active in equilibrium. As this is not in line with empirical evidence, we chose not to characterize this equilibrium and instead to concentrate on the separating PBE.

Assumptions on the product market profits In assumption 2, we have assumed $\frac{d\Pi_A(f,g)}{df} > 0$ and $\frac{d\Pi_N(f,g)}{df} < 0$. While it is a reasonable assumption, which is in line with a large class of oligopoly models comprising, among many others, the model of Farrell and Shapiro (1990) or Cournot models with linear demand, in which R&D leads to a reduction in unit production cost or an improvement in perceived product-quality, one may ask whether this assumption is necessary for our results.

If we assumed instead $\frac{d\Pi_A(f,g)}{df} - \frac{d\Pi_N(f,g)}{df} > 0$ with $\frac{d\Pi_N(f,g)}{df} > 0$, all our results would continue to hold, except for two. First, instead of always being larger (Proposition 3), the industry profits net of development costs in case of incumbent-financed development of a good innovation can be either larger or smaller than the ones in case of VC-backed development. Whether they are larger or smaller depends on the relative size of $\frac{d\Pi_A(f,g)}{df}$ and $\frac{d\Pi_N(f,g)}{df}$ as well as on the number of incumbents, I. Second, with $\frac{d\Pi_N(f,g)}{df} > 0$, the abnormal returns to the stocks of acquirers and non-acquirers would no longer be less positive/more negative after an announcement of a venture capital-backed private company than after other private acquisitions (contrary to Propositions 7 and 8). This would not be in line with the empirical evidence presented by Gompers and Xuan (2008).[22]

Initial public offerings A large part of the existing literature on VCs and Angel investors concentrates on exit by IPOs. We are modeling innovation for an existing market. Hence, as mentioned before, exit through IPO would potentially lead to an additional competitor in the market. As there is an existing market, there are incumbents, which can bid for the developed innovation in (or before) the IPO, and whose bid for the late-stage entrepreneurial company would always be higher than that of a potential entrant. Therefore, our decision to model the VCs' exit as a sale to incumbents is without consequences for the results of our model.

Furthermore, also empirically M&As are an important exit mode in terms of frequency and value created as shown, e.g., by Cumming and MacIntosh (2003) and Cochrane (2005): In U.S. data from VentureOne from the last decade, exits through M&As generated consistently higher aggregate value than exits through IPOs despite the similar frequency of M&As and IPOs.

On the acquirer's side, Granstrand and Sjölander (1990), Hall et al. (1990), Lerner and Merges (1998), and OECD (2007) present evidence that acquisitions are important means of established firms to access new technologies. To acquire those technologies, incumbents need to bid for entrepreneurial companies that received financing from VCs, giving credibility to their participation even if an IPO is the chosen mode of exit.

Other motivations for patenting Our focus on the signaling function of patenting does not exclude other motivations for it, such as the protection of intellectual property against imitation. As VC and Angel-backed companies eventually are either sold to a firm in the product-market or enter the product-market themselves, the extent of their patenting activity originating in these motivations is assumed to be the same for VCs (and Angels) and incumbents.

[22]We are grateful to Kieron Meagher for pointing us into this direction.

6 Concluding remarks

In this paper, we have proposed a theory of venture capital activity in markets in which asymmetric information problems and oligopolistic externalities are present. We have shown that better informed VCs have an incentive to signal the wealth-creating capacity of their investments prior to exiting. This signaling incentive increases the VCs' patenting intensity, investments, as well as the long-term performance of the companies they invest in. However, it also substantially increases investment costs and the late-stage acquisition price. We have shown that this theory reconciles seemingly contradictory empirical evidence: (i) despite their superior long-run performance, stock markets react more negatively to acquisitions of venture capital-backed companies than to other private acquisitions; and (ii) industries with higher venture capital activity show higher patent count, but not higher total factor productivity growth.

In the previous literature, active VCs have been shown to play an important role in solving moral hazard problems. We identify another important role of VCs and Angels, that of selecting and supporting new entrepreneurial ventures, and signaling their wealth-creating capacity to potential acquirers by strategic over-patenting. Consequently, our model predicts that the emergence of VCs whose specialty is scrutinizing business plans not only helps the market select good projects but, due to the signaling effect, also creates a more vigorous development of innovations in the market and higher rewards for entrepreneurs who discover new innovations. These higher rewards, in turn, increase the entrepreneurs' incentive to innovate.

The VCs' higher level of productive investment explains that venture capital-backed acquisitions have a better long-run operational performance than other private acquisitions as shown by Gompers and Xuan (2008). However, it also leads to a greater efficiency advantage of the acquiring firm over its competitors and therefore to substantially higher acquisition prices of venture capital-backed companies at the late stage since incumbents bid aggressively to preempt rivals from obtaining them. We thereby explain the stronger negative stock market reaction to announcements of venture capital-backed acquisitions as compared to other private acquisitions as found by Gompers and Xuan (2008).

Moreover, this explanation also sheds light on Ueda and Hirukawa's (2008) seemingly contradictory observations. The need to signal their investment's wealth-creating capacity by VCs combined with the exploitation of competition between incumbents for the acquisition of the entrepreneurial company lead to their higher patenting intensity as found by Ueda and Hirukawa (2008). As we find, VCs have incentives to invest up to a level that is associated with lower total profits than those associated with the level of investment chosen by incumbents. This result has a negative and a positive impact on total factor productivity growth. On the one hand, because typical measures of total factor productivity growth include factors used for research and development,[23] these measures capture a negative effect due to over-investment in research and development. On the other hand, the VCs' over-investment enables them to exploit strategic product-market effects, which increase the compensation entrepreneurs receive for their early-stage innovations and therefore their incentives to engage in innovative activities. This impacts positively on total factor productivity growth. These two effects may cancel each other out, explaining why venture capital activity has been found to have no impact on total factor productivity as evidenced by Ueda and Hirukawa (2008).

[23]See Bartelsman and Gray (1996) for a detailed description of the total factor productivity data used, e.g., by Ueda and Hirukawa (2008).

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Appendix

A Proof of Lemma 2

First, compare $v_{ij}(s)$ and $v_{ii}(s)$. Recall that VCs develop good innovations to a greater extent than incumbents. Thus, a non-acquirer's profit if a VC obtains a good innovation in stage 1 is lower than its profit if a competing incumbent acquired it, $\Pi_N\left(f_j^g, g\right) < \Pi_N\left(f_i^g, g\right)$. Therefore, for all $\lambda^s \in]0,1]$, $v_{ii}(s) < v_{ij}(s)$.

Second, compare $v_j(g)$ and $v_{ij}(s)$. Denote by $v_{ij}^c(s)$ and $v_{ij}^u(s)$ the incumbent's valuation if the VC is constrained and unconstrained in its investment choice after having observed signal s. Consider λ^s close to 1. Suppose the VC's incentive compatibility constraint is not binding. As f_i^g maximizes $\Pi_A(f,g) - C(f,g)$, whereas f_j^g does not, $v_{ij}^u(s) > v_j^u(g)$: Incumbents are willing to pay more than VCs to obtain the innovation to avoid the over-investment by a VC. Now suppose the VC's incentive compatibility constraint is binding. In this case, he must invest more than its unconstrained optimal amount to signal an innovation's good nature, that is, it must choose a patenting intensity $f_j^c > f_j^u$. This higher patenting intensity reduces the non-acquirers' product-market profits, and increases the incumbents' first-stage valuation. It also reduces profits of the VC, and decreases the VCs' first-stage valuation. Thus also $v_{ij}^c(s) > v_j^c(g)$. Now consider λ^s close to 0. In this case, the incumbents' valuation, $v_{ij}(s)$ is close to zero, and therefore smaller than the VCs' valuation, $v_j(g)$. As for λ^s close to 0, $v_{ij}(s) < v_j(g)$ and for λ^s close to 1, $v_{ij}(s) > v_j(g)$, and as $v_{ij}(s) - v_j(g)$ is continuous and monotonously increasing in λ^s, there exists a λ^p such that for $\lambda^s < \lambda^p$, $v_{ij}(s) < v_j(g)$ and for $\lambda^s > \lambda^p$, $v_{ij}(s) > v_j(g)$. The superscript p in λ^p, anticipates that for $\lambda^s > \lambda^p$ incumbents *preemptively acquire* early-stage innovations.

Third, compare $v_j(g)$ and $v_{ii}(s)$. Suppose the VC's incentive compatibility constraint is not binding. As f_j^u maximizes $\Pi_A(f,g) - \Pi_N(f,g) - C(f,g)$, whereas f_i^g does not, $v_j^u(g) > v_{ii}(s)$ for any λ^s. A binding incentive compatibility constraint in the VCs' patenting decision in stage 2 depresses their valuation $v_j(g)$, whereas it does not affect $v_{ii}(s)$. Therefore, if it is sufficiently easy to patent innovations with low wealth-creating capacity and if the VCs' advantage in selecting early-stage entrepreneurial companies is sufficiently small, a low valuation of VCs for a good innovation coincides with a high valuation of incumbents that make an offer for the early-stage innovation to avoid a product-market competitor's preemptive acquisition. In that case, we observe $v_j^c(g) < v_{ii}(s)$. Denote the λ^s such that $v_j^c(g) = v_{ii}(s)$ by λ^{ii}.

B Proof of Proposition 4

Proof. Competition among the symmetric VCs for the acquisition implies the equilibrium price cannot be lower than $v_j(g)$. Moreover, no VC has an incentive to make a higher offer. Assume $\lambda^s < \lambda^p$. In this case, $v_{ij}(s) < v_j(g)$, so that no incumbent would be able to offer more than the VCs. Given that in this case a VC wins if the innovation is good and all VCs offer zero if it is bad, incumbents always offer zero as long as $\lambda^s < \lambda^p$. This shows part 1. Assume $\lambda^p < \lambda^s < \lambda^{ii}$. Here, $v_{ii}(s) < v_j(g) < v_{ij}(s)$. Consider the equilibrium candidate in which one incumbent offers $v_j(g)$ and the second highest offer is by a VC that offers $v_j(g) - \varepsilon$. Note that the acquiring incumbent does not deviate to a lower offer since it benefits in expectation from an acquisition at $P_1 = v_j(g)$ by avoiding the excessive investments by VCs, which would otherwise occur in case the innovation turns out to be good. This follows from the acquiring incumbent's net profit being $\pi_A^* = \lambda^s\left(\Pi_A\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right) - v_j = v_{ij} - v_j + \lambda^s \Pi_N\left(f_j^g, g\right) > \lambda^s \Pi_N\left(f_j^g, g\right)$. Deviating to a higher offer is not profitable for the winning incumbent. Moreover, other incumbents do not challenge an acquisition by a rival firm since they benefit from weaker market competition, while not bearing the cost of the acquisition. This follows from the fact that $\lambda^s \Pi_N\left(f_i^g, g\right) = \lambda^s\left(\Pi_A\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right) - v_{ii} > \lambda^s\left(\Pi_A\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right) - v_j = \pi_A^*$. This shows part 2. Assume $\lambda^{ii} < \lambda^s$. Here, $v_j(g) < v_{ii}(s) < v_{ij}(s)$. Competition among symmetric incumbents for the acquisition implies the equilibrium price cannot be lower than $P_1 = v_{ii}(s)$. Moreover, no incumbent has an incentive to offer more. This shows part 3. ∎

C Equilibrium characterization in terms of a and q

To characterize the equilibrium of our model in terms of a and q, use the following properties of λ^g and λ^b. For $a = \frac{1}{2}$, $\lambda^g = \lambda^b = q$. For $a = 1$, $\lambda^g = 1$ and $\lambda^b = 0$. For $q \to 1$, $\lambda^g \to 1$ for all a; and for $q \to 0$, $\lambda^b \to 0$ for all a.

Suppose first that the VCs' incentive compatibility constraint is not binding, i.e., that it is sufficiently more difficult to patent innovations with low than those with high wealth-creating capacity. In this scenario, consider first an environment in which almost no entrepreneurial innovations possess a high wealth-creating capacity. Then $q \to 0$ and consequently the incumbents' posterior probability after observing a bad signal, $\lambda^b \to 0$ for any $a \in \left[\frac{1}{2}, 1\right]$. This implies $v_{ij}(b) < v_j(g)$ for any $a \in \left[\frac{1}{2}, 1\right]$. After a good signal, their posterior probability λ^g depends on a. For $a = \frac{1}{2}$, $\lambda^g = q \to 0$ while for $a = 1$, $\lambda^g = 1$, which implies $v_{ij}(g) < v_j(g)$ for sufficiently small a and $v_{ij}(g) > v_j(g)$ for sufficiently large a.

[Insert figure 3 here.]

In the left-hand side panel of Fig. 3 we draw valuations $v_j^u(g)$, $v_{ij}^u(g)$, and $v_{ij}^u(g)$ as functions of a in an environment in which q is relatively small. For all a, the incumbents' valuation after a bad signal, $v_{ij}^u(b)$, is smaller than the VCs' valuation for a good innovation $v_j^u(g)$. Furthermore, the incumbents' valuation after a good signal, $v_{ij}^u(g)$, is larger than the VCs' valuation for a good innovation, $v_j^u(g)$, if and only if the incumbents' signal is sufficiently precise, i.e., if $a > a^p(g)$ in the left-hand panel of Fig. 3. Thus, in an environment characterized by a relatively low prior probability of success, incumbents preemptively acquire early-stage entrepreneurial ventures if and only if they received a good signal ($s = g$) *and* are sufficiently precise in their assessment of these ventures (a large). In the left-hand side panel of Fig. 3, this is true for the shaded area. They offer zero for the ventures if their assessment is too imprecise (a small) or if they received a bad signal ($s = b$). Fig. 3 also shows valuations $v_{ii}(g)$ and $v_{ii}(b)$ as functions of a. Note how for every a and q, $v_{ii}(s) < v_{ij}^u(s)$ and $v_{ii}(s) < v_j^u(g)$. Therefore, in this environment, the early-stage price equals the VCs' valuation for a good innovation, $P_1^* = v_j^u(g)$ irrespective of whether a VC or an incumbent finances the entrepreneurial venture.

Consider now an environment in which almost all entrepreneurial innovations possess a high wealth-creating capacity. In such an environment, $q \to 1$ and consequently the incumbents' posterior probability after observing a good signal, $\lambda_g \to 1$ for any $a \in \left[\frac{1}{2}, 1\right]$. This implies $v_{ij}(g) > v_j(g)$ for any $a \in \left[\frac{1}{2}, 1\right]$. After a bad signal, their posterior probability λ_b depends on a. For $a = \frac{1}{2}$, $\lambda_b = q \to 1$ while for $a = 1$, $\lambda_b = 0$, which implies $v_{ij}(b) > v_j(g)$ for sufficiently small a and $v_{ij}(b) < v_j(g)$ for sufficiently large a.

In the right hand side panel of Fig. 3 we depict the valuations $v_j^u(g)$, $v_{ij}^u(g)$, and $v_{ij}^u(b)$ as functions of a in an environment in which q is relatively large. For all a, the incumbents' valuation after a good signal, $v_{ij}^u(g)$, is larger than the VCs' valuation for a good innovation, $v_j^u(g)$. However, the incumbents' valuation after a bad signal, $v_{ij}^u(b)$, is larger than the VCs' valuation for a good innovation, $v_j^u(g)$, if and only if the incumbents' signal is sufficiently imprecise, i.e., if $a < a^p(b)$ in the right-hand panel of Fig. 3. Thus, in this environment, incumbents preemptively acquire all entrepreneurial ventures for which they received a good signal, irrespective of how precise this signal is. Furthermore, they offer a positive amount for ventures after they received a bad signal if and only if the signal is sufficiently *imprecise*. As in the left-hand side panel, for any $a \in \left[\frac{1}{2}, 1\right]$, $v_{ii}(s) < v_j^u(g)$ and, therefore, $P_1^* = v_j^u(g)$ irrespective of whether a VC or an incumbent finances the entrepreneurial venture.

[Insert figure 4 here.]

Suppose now that the VCs' incentive compatibility constraint is binding, i.e., it is not sufficiently more difficult to patent bad innovations than it is to patent good innovations. In Fig. 4 we show the impact of such a binding constraint. Note how the binding incentive compatibility constraint depresses the VCs' valuation, i.e., $v_j^c(g) < v_j^u(g)$, and how it increases the incumbents' valuation for which the outside option is that a VC backs the entrepreneurial company, i.e., $v_{ij}^c(g) > v_{ij}^u(g)$, and $v_{ij}^c(b) > v_{ij}^u(b)$. Note also that whether or not the incentive compatibility constraint binds does not affect the incumbents' valuation for which the outside option is that a product-market rival acquires the innovation in the early stage, i.e., $v_{ii}(g)$ and $v_{ii}(g)$ are not affected. The consequence is that the incumbents' valuation exceeds the VCs' valuation for more (a, q) −combinations and thus there are more early (preemptive) acquisitions than if the incentive compatibility constraint (2) were not binding. As in Fig. 3, also in Fig. 4, for every $a \in \left[\frac{1}{2}, 1\right]$, $v_{ii}(s) < v_j^c(g)$ and therefore, for every $a \in \left[\frac{1}{2}, 1\right]$, $P_1^* = v_j^c(g)$.

Finally, consider a situation in which there is almost no difference in the difficulty to patent bad and good innovations, as depicted in Fig. 5. As compared to Fig. 4, here the incumbents' valuation, $v_{ij}^c(s)$, is further inflated and the VCs' valuation, $v_j^c(g)$, is further depressed. If in this case the incumbents' signal is sufficiently precise, i.e., if $a > a^{ii}(g)$ in Fig. 5, their valuation $v_{ii}(g)$ surpasses the VCs' valuation for a good innovation, $v_j^c(g)$. As a consequence, incumbents with good signals of precision larger than $a^{ii}(g)$ offer $v_{ii}(g)$.

[Inser figure 5 here.]

Any further reduction in the difference of the difficulty to patent good and bad innovations further reduces $v_j^c(g)$. Thus, for some parameter constellations, there exists even an $a^{ii}(b)$ such that for $a > a^{ii}(b)$, $v_j(g) > v_{ii}(b)$ and for $a < a^{ii}(b)$, $v_j(g) < v_{ii}(b)$.

D Derivation of the difference in abnormal returns

Proof. The difference in abnormal returns between early, preemptive and late acquisitions is

$$R_A^p - R_A^v = \lambda^s \left[\Pi_A\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right] - \left[\Pi_A\left(f_j^g, g\right) - C\left(f_j^g, g\right)\right] + \left(1 - \lambda^s\right)\Pi_i(0, b). \quad (20)$$

We observe early, preemptive acquisitions if and only if $v_{ij}(s) > v_j(g)$, i.e., if and only if

$$\lambda^s \left[\Pi_A\left(f_i^g, g\right) - \Pi_N\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right] > \Pi_A\left(f_j^g, g\right) - \Pi_N\left(f_j^g, g\right) - C\left(f_j^g, g\right) \quad (21)$$

$$\Leftrightarrow$$

$$\lambda^s \left[\Pi_A\left(f_i^g, g\right) - C\left(f_i^g, g\right)\right] - \left[\Pi_A\left(f_j^g, g\right) - C\left(f_j^g, g\right)\right] > \left(1 - \lambda^s\right)\Pi_N\left(f_j^g\right). \quad (22)$$

As the right hand side of Eq. (22) is positive, so is the left hand side. Therefore, in case of a preemptive acquisition, Eq. (20) is positive. ■

Strict usefulness clause implementation

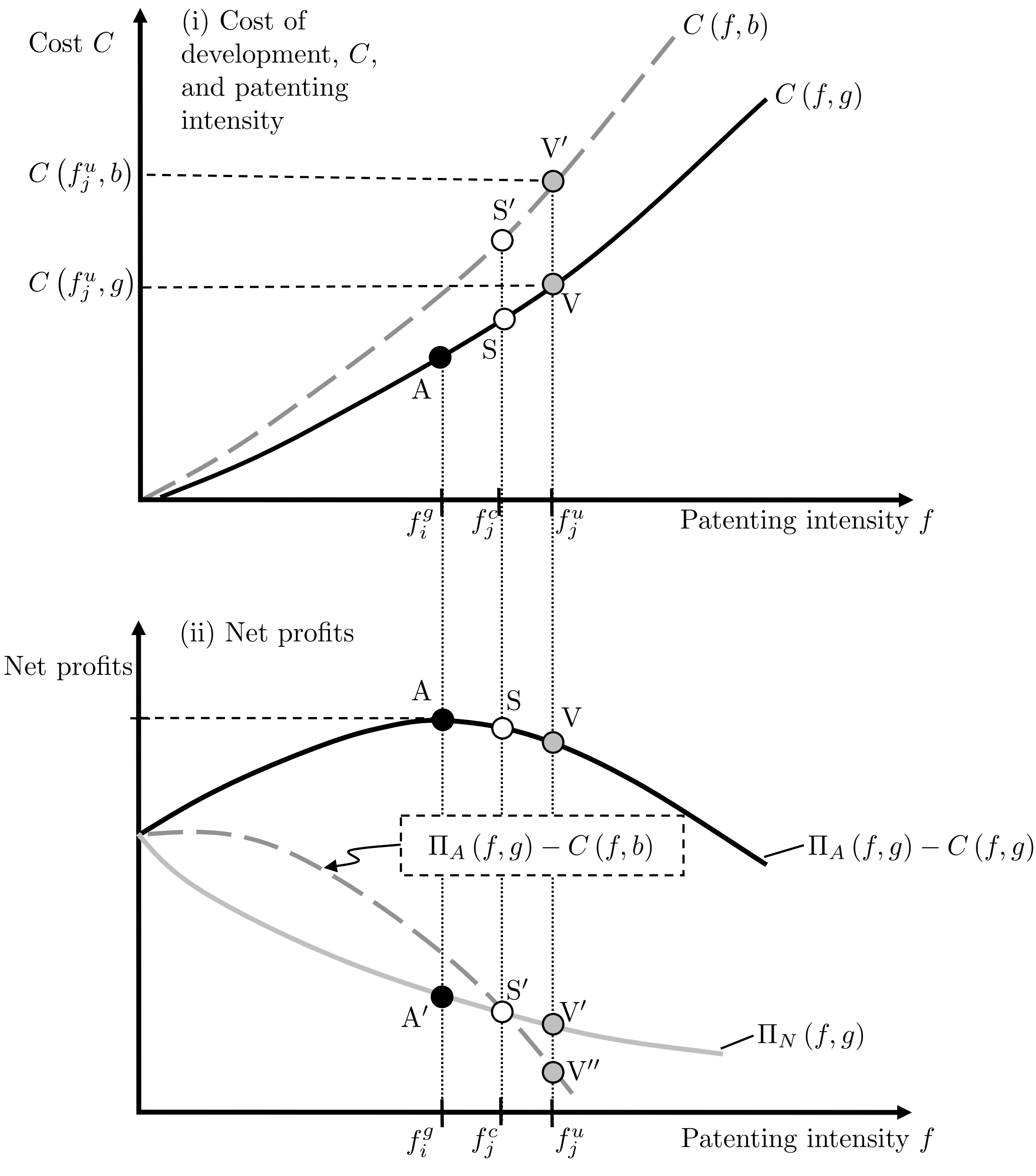

Figure 1: If patenting bad innovations is sufficiently more costly than patenting good innovations, the VCs' incentive compatibility constraint is not binding. They invest such that their patenting intensity is $f_j^u > f_j^c$.

Lax usefulness clause implementation

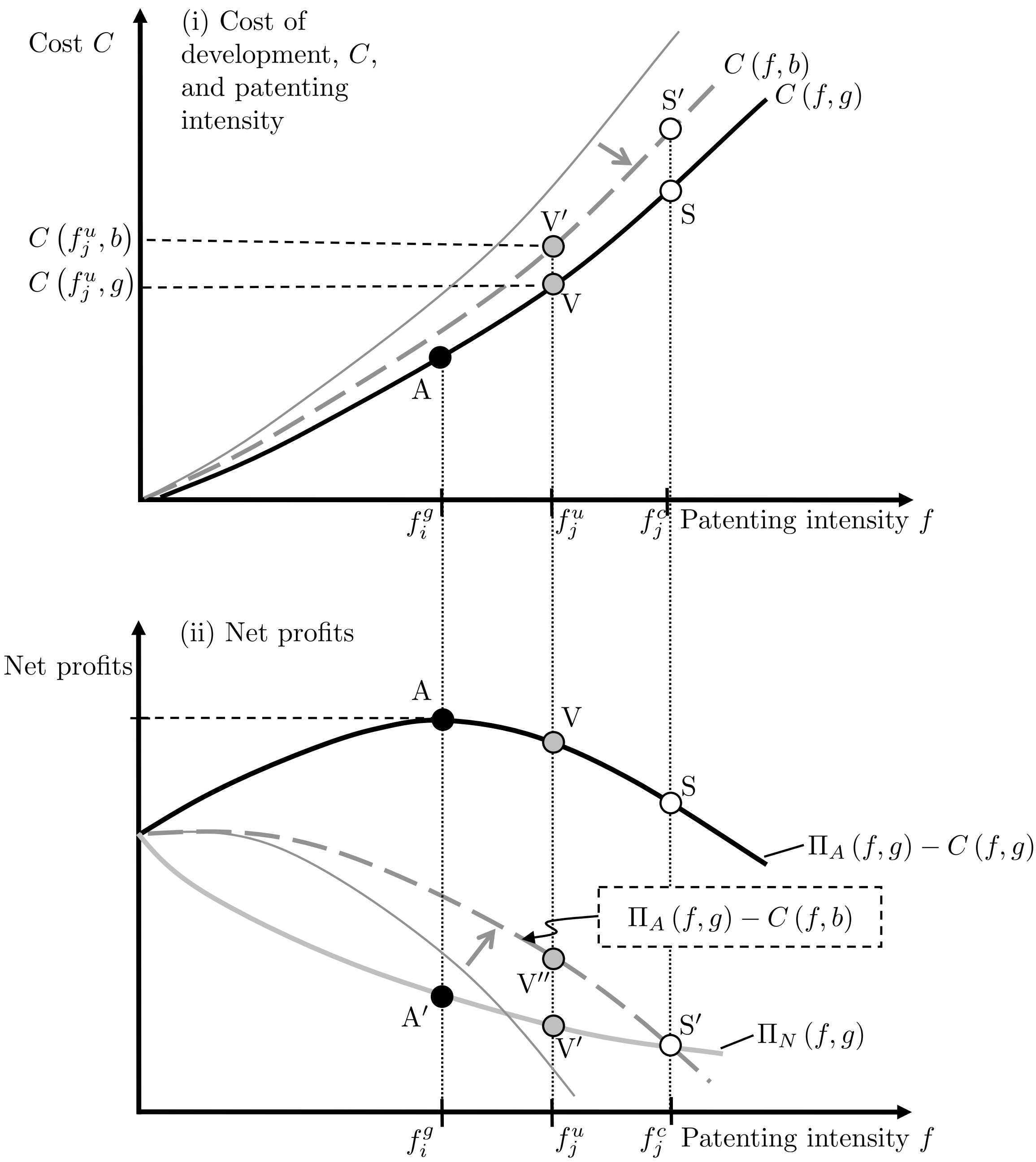

Figure 2: If patenting bad innovations is not sufficiently more costly than patenting good innovations, the VCs' incentive compatibility constraint is binding. They need to invest beyond the value that would maximize their profits absent information asymmetries and their patenting intensity is $f_j^c > f_j^u$.

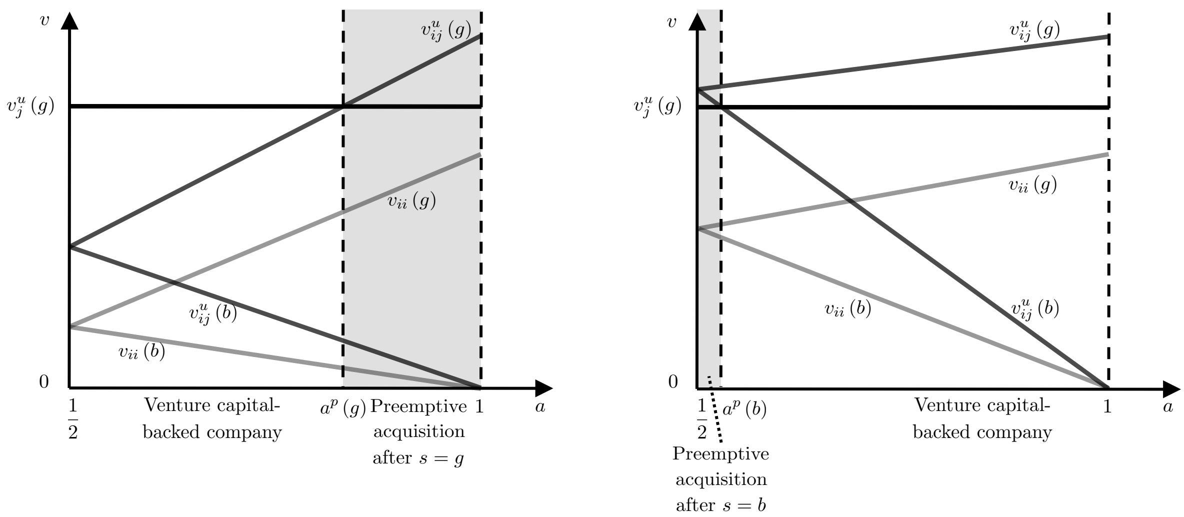

Figure 3: Valuations and equilibrium if it is sufficiently more difficult (costly) to patent bad than good innovations (VCs are unconstrained in their patenting choice). Notation: a is the incumbents' signal's precision, v are valuations. $v_j^u(g)$ is the VCs' valuation for a good innovation; $v_{ij}^u(g)$ and $v_{ij}^u(b)$ are the incumbents' valuation after a good and a bad signal for which the outside option is the formation of an VC-backed entrepreneurial company; and $v_{ii}(g)$ and $v_{ii}(b)$ are the incumbents' valuation after a good and a bad signal for which the outside option is an early acquisition by a rival. Superscript u signifies that a VC is unconstrained in its patenting choice. Left panel: Low prior probability q that entrepreneurial ventures possess high wealth-creating capacity. Incumbents do not preemptively acquire any ventures with a bad signal. They preemptively acquire ventures with a good signal if $a > a^p(g)$. Right panel: High prior probability q that entrepreneurial ventures possess high wealth-creating capacity. Incumbents preemptively acquire all ventures with good signals. They acquire ventures with bad signals if $a < a^p(b)$.

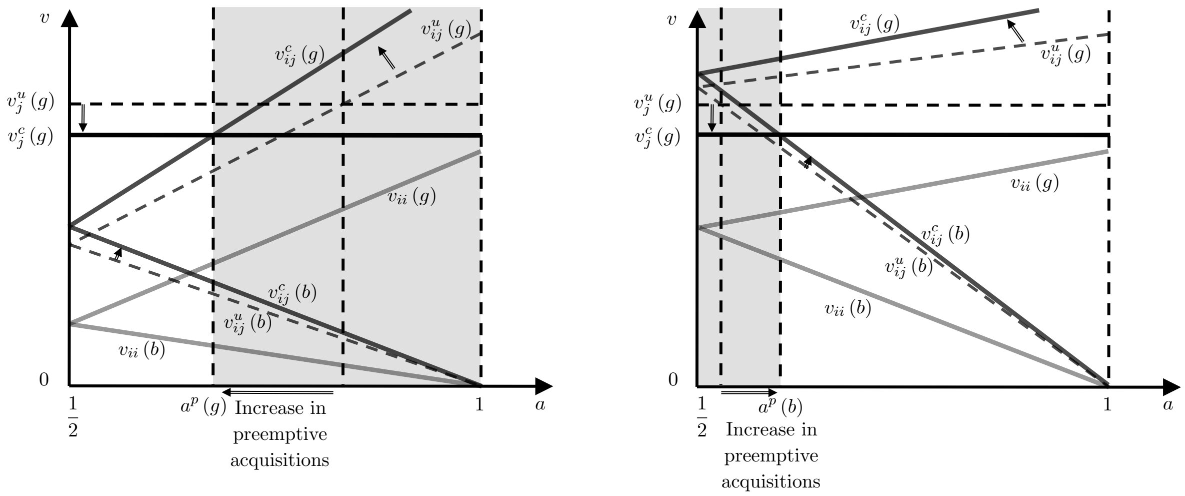

Figure 4: Valuations and equilibrium if it is not sufficiently more difficult (costly) to patent bad than good innovations. Notation: a is incumbents' signal's precision, v are valuations. $v^u_j\,(g)$ is the VCs' valuation for a good innovation; $v^u_{ij}\,(g)$ and $v^u_{ij}\,(b)$ are the incumbents' valuation after a good and a bad signal for which the outside option is the formation of a VC-backed entrepreneurial company; and $v_{ii}\,(g)$ and $v_{ii}\,(b)$ are the incumbents' valuation after a good and a bad signal for which the outside option is an early acquisition by a rival. Superscripts u and c respectively signify that a VC is unconstrained and constrained in its patenting choice. Left panel: Low prior probability q that entrepreneurial ventures possess high wealth-creating capacity. Right panel: High prior probability q that entrepreneurial ventures possess high wealth-creating capacity. The binding incentive compatibility constraint results in a lower $v_j\,(g)$ and higher $v_{ij}\,(g)$ and $v_{ij}\,(b)$. More entrepreneurial ventures are preemptively acquired and fewer entrepreneurial companies are backed by a VC.

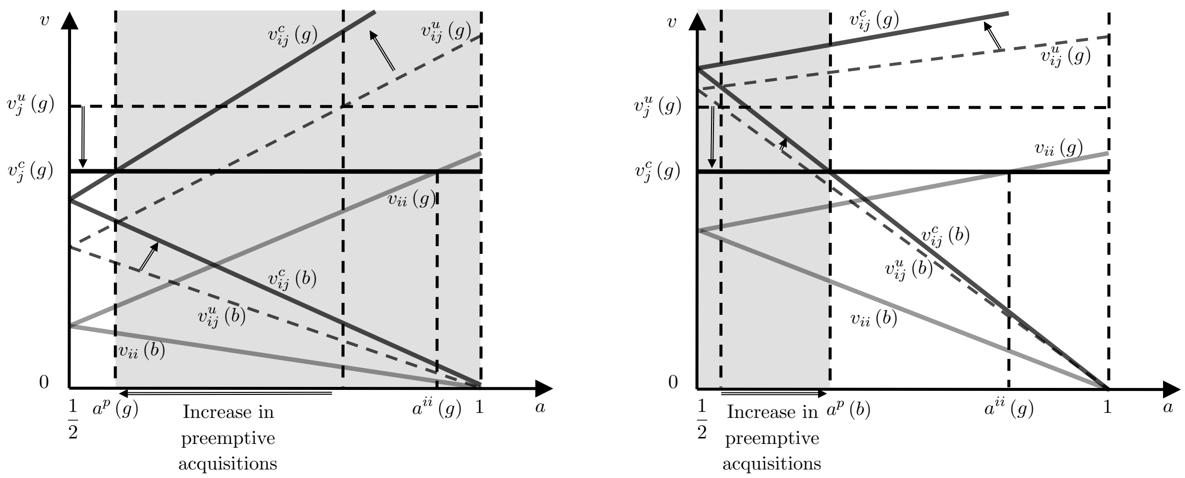

Figure 5: Valuations and equilibrium if it is only a little more difficult (costly) to patent bad than good innovations. Notation: a is incumbents' signal's precision, v are valuations. $v_j^u(g)$ is the VCs' valuation for a good innovation; $v_{ij}^u(g)$ and $v_{ij}^u(b)$ are the incumbents' valuation after a good and a bad signal for which the outside option is the formation of a VC-backed entrepreneurial company; and $v_{ii}(g)$ and $v_{ii}(b)$ are the incumbents' valuation after a good and a bad signal for which the outside option is an early acquisition by a rival. Superscripts u and c respectively signify that a VC is unconstrained and constrained in its patenting choice. Left panel: Low prior probability q that entrepreneurial ventures possess high wealth-creating capacity. Right panel: High prior probability q that entrepreneurial ventures possess high wealth-creating capacity. The difficulty to signal by means of patents depresses $v_j(g)$ by so much that $v_j(g) < v_{ii}(g)$ and incumbents offer $v_{ii}(g)$.