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THE ORGANIZATION OF THE INNOVATION INDUSTRY: ENTREPRENEURS, VENTURE CAPITALISTS AND OLIGOPOLISTS

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ABSTRACT

The Organization of the Innovation Industry: Entrepreneurs, Venture Capitalists and Oligopolists*

Exit of venture-backed firms often takes place through sales to large incumbent firms. We show that in such an environment, venture-backed firms have a stronger incentive to develop basic innovations into commercialized innovations than incumbent firms, due to strategic product market effects. This will increase the price for basic innovations, thereby triggering more such innovations by entrepreneurs. Consequently, a venture capital market implies that more innovations are created, and that these become better developed. Moreover, we show that to exist in equilibrium, venture capitalist must be substantially more efficient, otherwise incumbents will pre-empt venture capitalists entering the market by acquiring basic innovations

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1. Introduction

There is a growing awareness of the role played by venture capitalists in the innovation process.[1] Venture capitalists have come to specialize in financing early-stage investment for entrepreneurs and providing business experience.[2] In a study on venture capital and innovation, Kortum and Lerner (2000) find increases in venture capital activity in an industry to be associated with significantly higher patenting rates. Moreover, Hellmann and Puri (2000) find venture capital to be associated with a significant reduction in the time required for bringing a product to the market. This poses the question of why venture-backed firms are more aggressive and more successful than incumbent firms in bringing commercialized innovations to the market.

The starting point of this paper is that the exit of the venture-backed firm often takes place by the acquisition of an incumbent firm.[3][4] Figure 1.1 depicts the quarterly value of exits through M&As and IPOs, respectively, in the US in the period 1999 to 2005. Note that M&As dominate as exit mode except in the beginning of the period. According to the *Economist* (1999)[5], the exit strategy of venture capital firms changed in the late 1990's from initial public offerings (IPOs) to exit by sale: *"Over the past year or so, however, venture-capital firms' exit strategy has changed. ... more and more*

[1] See, for instance, Gompers and Lerner (2001).

[2] Hellmann and Puri (2002) find evidence of US venture capital being related to a variety of professionalization measures, such as human resource policies, the adoption of stock options plans, and the hiring of a marketing VP. Bottazzi, Da Rin and Hellmann (2004) find similar evidence for European venture capital.

[3] For instance, Cochrane (2005) uses data over the period 1987 to June 2000 from the Venture-One database and shows that 20 % of the ventures were acquired, 21 % were IPOs, 9% went out of business, while 49% remained private. Cumming and MacIntosh (2003) found similar figures.

[4] Granstrand and Sjölander (1990) present evidence from Sweden and Hall (1990) presents evidence from the US that firms acquire innovative targets to gain access to their technologies. Bloningen and Taylor (2000) find evidence from US high-tech industries of firms making a strategic choice between the acquisition of outside innovators and in-house R&D. In the biotech industry, Lerner and Merges (1998) note that acquisitions are important for know-how transfers. OECD (2000, 2002) argues that established firms often acquire firms to access new technologies.

[5] "Easy way out", Feb 18 1999, *The Economist*.

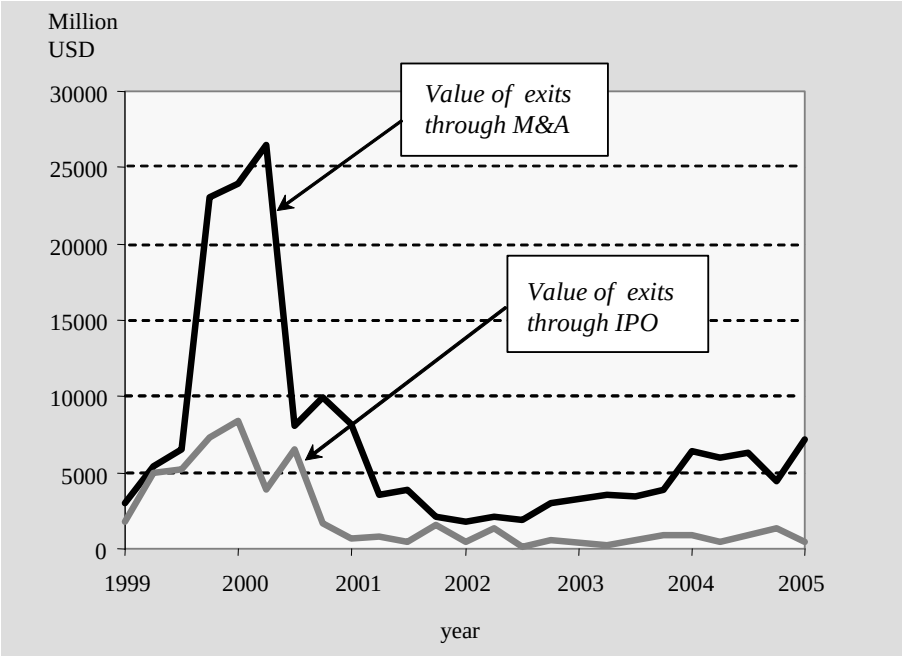

Figure 1.1: The value of exits through M&A and IPO in the US. Source: Thomson Venture Economics/National Venture Capital Association.

entrepreneurs are starting enterprises with the express purpose of being bought out in due course." Moreover, according to the *Economist* (1999), innovators know that incumbent firms in highly concentrated markets are those willing to pay the most for innovations, as indicated by the following quote: *"Companies like Cisco, Intel and Microsoft recognize the threat posed by nimble young firms getting technologies to market at unimaginable speeds," says Red Herring's Brian Taptich. "And they're willing to pay extremely high premiums to protect their franchises."*[6]

In the literature, informational advantages and abilities have been suggested to explain why venture capitalists are more aggressive and more successful in creating commercialized innovations.[7] We add to this literature by showing that venture-backed firms selling innovations to incumbents in concentrated markets have a stronger incentive to develop

[6] An example is Cerent, which was acquired by Cisco at $6.9 billion. See Hellmann (2004).

[7] See, for instance, Gompers and Lerner (2001) for an overview of the empirical literture and see, for instance, Keuschnigg and Nielsen (2004) for a theoretical contribution.

basic innovations into commercialized innovations than incumbent firms, due to strategic product market effects on the sales price of the innovation. In turn, this will increase the price of basic innovations, thereby triggering a larger number of such innovations by entrepreneurs. Consequently, the presence of a venture capital market implies that more basic innovations are created and better developed.

We present a model where a market is served by several incumbent firms competing in oligopoly fashion. In the initial stage of the interaction, there is an entrepreneur investing in an innovative activity that might lead to the creation of a *basic innovation* which may be a prototype, a product or a production process, which is novel but requires additional development for commercial use. But the entrepreneur cannot develop the basic innovation herself and, in a second stage, she may sell it to one of the incumbent firms. Alternatively, the entrepreneur can seek support from one among several venture capitalists competing to provide expertise and financial support to develop the basic innovation. Consequently, the role played by venture capital is to make it possible for the entrepreneur to develop her basic innovation into an asset ready for commercialized use. We model the sale of the basic innovation as a first-price perfect information auction, where incumbent firms and venture capitalists bid for the basic innovation. If the entrepreneur "sells" the basic innovation to a venture capitalist, the venture-backed firm invests in the development of the innovation, where further development will increase the possessor's profit, but decrease the profits of the rival incumbent firms in the product market. The venture-backed firm will then exit by selling the *developed* innovation at a first-price perfect information auction, where the incumbent firms are the potential buyers. If, on the other hand, an incumbent firm obtains the innovation directly in stage 1, the acquiring firm invests in development. Given the innovation and development pattern, the incumbent firms compete in oligopoly fashion in the product market, in the final stage. We assume all players in the model to be completely informed about their own and other players' characteristics. This allows us to clearly attribute market force effects, as opposed to, say, problems of incomplete

information which have been extensively studied in the literature.[8]

We first show that a venture-backed firm has an incentive to develop the basic innovation further than an incumbent firm, due to strategic product market effects.[9] The reason is that an incumbent firm only takes into account how its *own profit* increases when investing in development. The venture-backed firm, in contrast, takes into account how the *acquisition price* of the developed innovation is affected. In equilibrium, the acquisition price is shown to equal an incumbent firm's valuation of obtaining the developed innovation which, in turn, consists of the profit for this firm of obtaining the developed innovation net its profit, if it is obtained by a rival firm. The venture capitalist thus internalizes that investments in the development of the basic innovation increase in the acquisition price, not only by generating an increase in the acquirer's profit, but also through the negative impact on the non-acquirer's profit (due to the development of more competitive assets).

Then, we turn to the question of how the presence of a venture capital market affects entrepreneurs' incentives to innovate. In the policy debate, it has been argued that a well-functioning venture capital market will increase the innovative activity in the industry, thereby contributing to the economic growth of a country.[10] In line with this view, we show that the entrepreneurial effort to innovate is higher when venture capitalists support entrepreneurs to develop their basic innovations into developed innovations, as compared to a case where the incumbent directly acquires basic innovations. The reason is that a venture-backed firm maximizes the net acquisition price when determining the development level, which implies that it obtains a net acquisition price equal to an incumbent firm's maximum valuation of a developed innovation. Bidding competition among venture capitalists for such an opportunity then bestows the entrepreneur with a higher reward for successful innovation which, in turn, induces a higher entrepreneurial effort to innovate.

[8] See Gompers and Lerner (2001) for an overview and, for instance, Kaplan and Strömberg (2001), on the principal-agent conflict between buyers and sellers.

[9] Hellmann and Puri (2000) provide empirical evidence of venture capital financing being related to product market strategies and outcomes of start-ups.

[10] See, for instance, OECD (1999) and European Commission (1995, 1999).

A further result derived is that when venture capitalists and incumbent firms are equally efficient in developing basic innovations and compete to gain control over these, preemptive acquisitions by incumbents occur, since incumbent firms take into account that venture-backed firms will invest more aggressively in development, as explained above. Preemptive acquisitions by incumbent firms thus preempt such, for them, excessive investments in development. However, it is also shown that the presence of venture capitalists as potential financiers of entrepreneurial firms increases the acquisition price and hence, the entrepreneurial efforts to innovate. This follows from the fact that venture-backed firms would invest more aggressively in development to resell developed inventions to incumbent firms. As a consequence, to obtain the entrepreneur's innovation, the acquiring incumbent firm must at least pay the entrepreneur a price for the innovation matching the venture-backed firms' valuations, which exceeds the prevailing price if only incumbents were to bid.

To our knowledge, no paper in the literature on venture capital deals with the venture capitalists' role in the organization of the innovation industry, where the exit of the venture-backed firm takes place by the acquisition of an oligopolist.[11] More in general, this paper might be seen as a contribution to the literature on industrial structure and innovation.[12] We extend this literature by allowing for the interaction between entrepreneurs, venture capitalists and oligopolist; an interaction which in the policy debate has been argued to be of great importance for the functioning of the innovation industry.

This paper could also be seen as a contribution to the literature on auctions with

[11] See Hellmann (2002) for one of the few studies where venture capitalists compete with established firms financing entrepreneurs. The author shows that if and only if the innovation is a complement to the established firm's business, the established firm will finance the project. However, oligopolistic effects are abstracted away, which is the focus of our paper.

[12] See pages 630-643 in Scherer and Ross (1990) for an overview. See Kranton and Minehart (2000) and Inderst and Wey (2003) for some recent contributions studying the interdependency between vertical structure and incentives to invest.

See Baumol (2002) for a description of the innovation industry.

externalities.[13] [14] A crucial feature of the models in that literature, which we share, is that the potential buyers of the asset for sale will exert externalities on each other after the auction and the ownership of the asset for sale will affect the strength of these externalities. We add to this literature by endogenizing the productivity of the assets sold in an environment where this productivity is affected by both an ex ante investment of the seller and an ex post investment of the buyer. It is then shown that due to the difference in incentives between the seller and the buyer (the former maximizes the sales price net of investment costs and the latter maximizes profits), the seller has an incentive to choose a higher productivity of the assets than the buyer's optimal ex ante choice. In effect, the seller overinvests relative to the buyer's optimum to "extort" a higher payment from the buyer for not diluting the buyer's profits by selling to a rival.

The model is spelled out in Section 2. In Section 3, we explore how the incentives to develop basic innovations differ between venture-backed and incumbent firms. In Section 4, we determine the ownership pattern of basic innovations and study the effects of venture capital on the incentive for basic innovations. In Section 5, we study how efficiency differences between venture capital firms and incumbent firms and the return to investment affect the equilibrium organization and the functioning of the innovation industry. In Section 6, we explore how robust is the finding that the venture backed firms have a stronger incentive to develop basic innovations into developed innovations by allowing for investment by the non-acquiring incumbents and for different selling procedures of the innovations (venture-backed firm). Section 7 concludes.

[13] See, for instance, Jehiel, Moldovanu and Stacchetti (1996) and Jehiel and Moldovanu (1996, 2000).

[14] This paper is also related to the literature on patent licensing, where a licence is sold at an auction and where the potential buyers are competing in a downstream market. See, for instance, Katz and Shapiro (1996) and for an overview, see Kamien (1992). The paper is also related to the literature on the persistence of monopoly; see, for instance, Chen (2000), Gilbert and Newbery (2000) Ghemawat (1990) and Krishna (1993).

However, the size of the sold asset cannot be affected both by the seller and the buyer in those studies and thus, the focus of those papers differs from ours.

2. The Model

The model is illustrated in Figure 2.1. We consider an oligopoly industry served by a set $i \in \mathcal{I}$ of symmetric incumbent firms, where $\mathcal{I} = \{1, 2, .., i, ..., N_I\}$. There is also an entrepreneur, denoted E, which in stage zero invests in a research effort e that could lead to the creation of a unique productive asset, referred to as the *basic innovation.* If successful, this entrepreneur can sell the basic innovation to one of the incumbent firms in stage 1. Alternatively, the entrepreneur can seek support from a venture capitalist providing expertise and financial support to develop the basic innovation. Without this support, the entrepreneur cannot develop her basic innovation. Consequently, the role played by venture capital is to make it possible for the entrepreneur to develop her basic innovation into an asset ready for commercialized use. The entrepreneur may then choose from a set $j \in \mathcal{J}$ of symmetric venture capitalists, where $\mathcal{J} = \{1, 2, .., j, .., N_J\}$. The venture capitalists compete to lend the entrepreneur financing in return for equity holdings in the firm. To focus on product market effects as a determinant of the ownership of the basic innovation, we model the sale of the basic innovation as a first-price perfect information auction with incumbent firms and venture capitalists bidding for the innovation.

If the entrepreneur obtains financing and support from a venture capitalist j in stage 1, the venture-backed firm can, in stage 2, invest k_{V_j} in the development of the basic innovation, thereby creating a *developed innovation* where further development will increase the possessor's profit, but decrease the profits of the rival incumbent firms in the ensuing product market. In stage 3, the venture-backed firm j exits by selling the developed innovation at a first-price perfect information auction, where the N_I incumbent firms are the potential buyers of the *developed innovation.* An acquiring incumbent firm i may then make an additional investment in stage 4 to further develop the innovation. This investment is denoted by $k_{A_i}(k_{V_j})$. Note that since both incumbent firms and venture capitalists are ex-ante symmetric, we can drop the indexing and simply write $k_A(k_V) = k_{A_i}(k_{V_j})$.

If, on the other hand, an incumbent firm i obtains the innovation in stage 1, the

game moves directly to stage 4, and the acquiring firm invests k_{A_i} in development where, once more, ex-ante symmetry implies $k_A = k_{A_i}$. Finally, in stage 5, the incumbent firms compete in oligopoly interaction, setting an action x_i.

3. Venture capitalists and the incentives to develop innovations

Let us first examine how the incentives of venture-backed firms and incumbent firms to develop innovations differ, taking as given that the entrepreneur has succeeded with an innovation in stage 0. To *highlight* the product market effects on innovations and the presence of venture capital, we shall initially assume that incumbent firms and venture capitalists will only differ in objectives, but are otherwise symmetric in all other dimensions. An introduction of asymmetries between these agents will be introduced in Section 5.

To proceed, let us now assume that one of the venture capitalists has gained control over the basic innovation in stage 1. Hence, we proceed along the right-hand branch of the game tree in Figure 2.1.

3.1. Stage 5: Product-market equilibrium

Using backward induction, we start with the product market interaction in stage 5, where firm i chooses an action $x_i \in R^+$ to maximize its *direct* product market profit, $\Pi_i(x_i, \mathbf{x}_{-i}, k_A)$, which depends on its own and its rivals' market actions, x_i and $\mathbf{x}_{-i}$ (which is the $(N_I - 1) \times 1$ vector of actions taken by rival incumbent firms), as well as the total amount of development undertaken (by the acquiring incumbent and/or the venture-backed firm) on k_A. We may consider the action x_i as setting a quantity or a price, as will be shown in later sections. Thus, we assume that there exists a unique Nash-Equilibrium in actions, $\mathbf{x}^*(k_A)$, defined from the first-order condition (3.1):

$$\frac{\partial \Pi_i}{\partial x_i}(x_i^*, \mathbf{x}_{-i}^*; k_A) = 0, \tag{3.1}$$

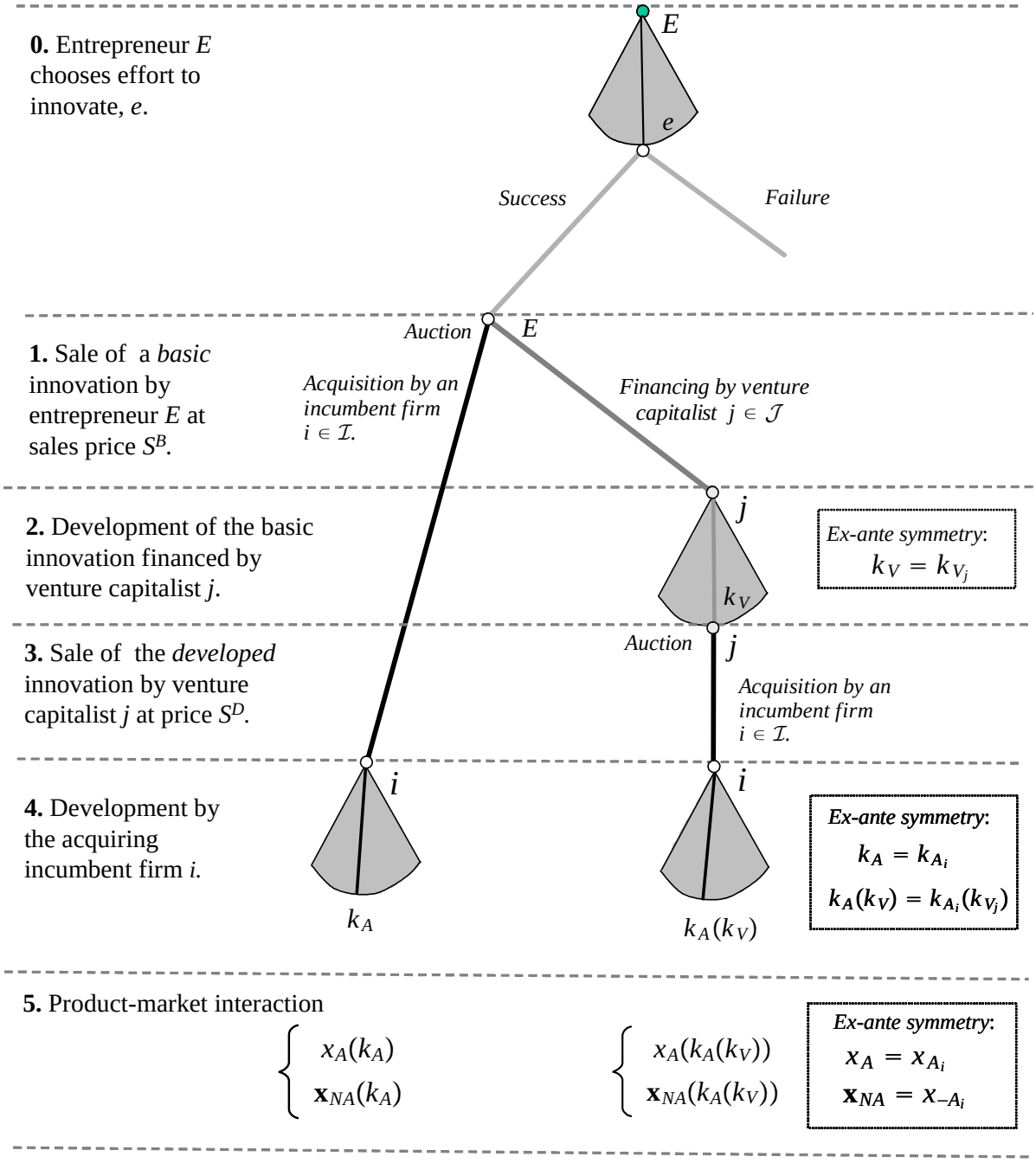

Figure 2.1: The structure of the game.

where $\mathbf{x}^*_{-i}$ is the actions by firm i:s rivals.

Using the ex-ante symmetry among incumbent firms, we only need to distinguish between two firm types, i.e. the acquiring firm (denoted A) and the non-acquiring firms (denoted NA). The actions are then simply $x_A = x_{A_i}$ and $x_{NA} = x_{-NA_i}$, where x_{NA} is one of the $(N_I - 1) \times 1$ arguments in the vector $\mathbf{x}_{NA}$ of symmetric actions taken by non-acquiring incumbent firms. Since the optimal actions for the acquirer (x^*_A) and the non-acquirers ($\mathbf{x}^*_{NA}$), respectively, only depend on k_A, we can define the *reduced-form* product market profits of the acquirer and a non-acquirer as direct functions of k_A:[15]

$$R_A(k_A) \equiv \Pi_A(x^*_A(k_A), \mathbf{x}^*_{NA}(k_A), k_A), \quad R_{NA}(k_A) \equiv \Pi_{NA}(\mathbf{x}^*_{NA}(k_A), x^*_A(k_A)). \tag{3.2}$$

We shall assume the reduced-form product market profit for a firm of type $h = \{A, NA\}$, $R_h(k_A)$, to have the following characteristics:

Assumption 1: $\dfrac{dR_A}{dk_A} > 0$ and $\dfrac{dR_{NA}}{dk_A} < 0$.

Assumption 1 states that the reduced-form product market profit for the acquirer is strictly increasing in investments for development in the innovation, whereas such investments strictly decrease the rivals' profits. To keep the exposition simple, we use the derivatives of reduced-form product market profits in Assumption 1, $\frac{\partial R_A}{\partial k_A}$ and $\frac{\partial R_{NA}}{\partial k_A}$, keeping in mind that these summarize the total effects on the product-market profits.[16]

[15] To save space, we write the arguments in $R_{NA}(k_A) \equiv \Pi_{NA}(\mathbf{x}^*_{NA}(k_A), x^*_A(k_A))$ with a slight abuse of notation. Note that $R_{NA}(k_A) = \Pi_{NA}(x^*_{NA}(k_A), \underbrace{x^*_{NA}(k_A), ..., x^*_{NA}(k_A)}_{N-2}, x^*_A(k_A))$.

[16] As also shown in Section 5.1, Assumption 1 holds in the Linear-Quadratic Cournot model, but it is also compatible with other oligopoly models. For example, Farrell and Shapiro (1996) show that under Cournot competition and general assumptions on demand and costs, an increase in capital for a firm (i) increases this firm's profit, while (ii) decreasing the profits of its competitors. Moreover, it can be shown that Assumption 1 extends to a linear Bertrand model with differentiated goods.

3.2. Stage 4: Optimal development by the acquiring incumbent

The acquiring incumbent firm's optimal choice of investment depends on the level of investment made by the venture-backed firm in stage 2. Assume that the acquirer faces a strictly convex investment function, $C(k)$, such that $C'(k) > 0$ and $C''(k) > 0$. Then, the maximization problem facing the acquiring incumbent firm in stage 4 can be written as follows:

$$\underset{\{k_A\}}{Max} : R_A(k_A) - C(k_A \mid k_V). \tag{3.3}$$

In (3.3), $C(k_A \mid k_V)$ denotes the total cost of investing k_A in development, given the choice of the venture capitalist, k_V:

$$C(k_A \mid k_V) = \int_{k_V}^{k_A} C'(k)dk. \tag{3.4}$$

The associated marginal cost of investing in development k_A is:

$$C'(k_A \mid k_V) = \begin{cases} 0 : k_A \leq k_V \\ C'(k_A) : k_A > k_V \end{cases}, \tag{3.5}$$

that is, investments in development acquired from the venture capitalist, k_V, can be used without any costs, whereas any additional investments in development are subject to the marginal cost, $C'(k_A)$, which is illustrated in Figure 3.1.

We assume $R_A(k_A) - C(k_A \mid k_V)$ to be strictly concave in k_A. The optimal choice by the acquiring firm if the venture capitalist were not to invest at all (i.e. $k_V = 0$), k_A^*, is then defined from the unconstrained optimum condition (3.6):

$$\frac{dR_A}{dk_A} = C'(k_A^*), \tag{3.6}$$

where k_A^* is illustrated in point A in the upper diagram in Figure 3.1.

For a given investment choice by the venture capitalist, k_V, the optimum investment level of development for the acquiring incumbent firm, k_A^{opt}, becomes:

$$k_A^{opt} = \begin{cases} k_V : k_A^* \leq k_V \\ k_A^* : k_A^* > k_V \end{cases}. \tag{3.7}$$

This optimal choice is illustrated in Figure 3.1. When $k_A^* \leq k_V$, the acquiring firm refrains from investing in development and only uses the (cost-less) investment from the venture capitalist, $k_A^{opt} = k_V$. Given that $k_A^* > k_V$, the optimal investment $k_A^{opt} = k_A^*$ is given from (3.6).

3.3. Stage 3: Sale of the developed innovation by the venture-backed firm

To focus on the product-market forces as the determinants of the equilibrium market structure, we model the acquisition process in stage 3 as a perfect information auction where the N_I incumbent firms simultaneously post bids, which are then accepted or rejected by the venture capitalist. Each incumbent firm announces a bid, b_i, for the developed innovation, where $\mathbf{b} = (b_1, ..., b_i, ...b_{N_I}) \in R^{N_I}$ is the vector of these bids. Following the announcement of $\mathbf{b}$, the developed innovation may be sold to one of the incumbents at the bid price, or remain in the ownership of the venture-backed firm.[17] The equilibrium acquisition price is denoted by S^D.

We now turn to incumbent firms' valuations of obtaining the developed innovation w_{II}, defined in (3.8). The first term shows the profit for an incumbent firm when possessing the innovation, the second term shows the profit if it is obtained by a rival incumbent firm:

$$w_{II} = \begin{cases} R_A(k_V) - R_{NA}(k_V) : & k_A^* \leq k_V \\ R_A(k_A^*) - C(k_A^* \mid k_V) - R_{NA}(k_A^*) : & k_A^* > k_V \end{cases}, \tag{3.8}$$

where $C(k_A^* \mid k_V) = \int_{k_V}^{k_A^*} C'(k)dk$. Note that since incumbent firms are symmetric ex-ante, their valuations are symmetric. It is then straightforward to derive the following lemma[18]:

[17] If more than one of the incumbent firms make such a bid, each such firm obtains the assets with equal probability. The acquisition is solved for Nash equilibria in undominated pure strategies. There is a smallest amount, ε, chosen such that all inequalities are preserved if ε is added or subtracted.

[18] The correct acquisition price is $w_{II} - \varepsilon$, but to simplify the presentation, we use w_{II}.

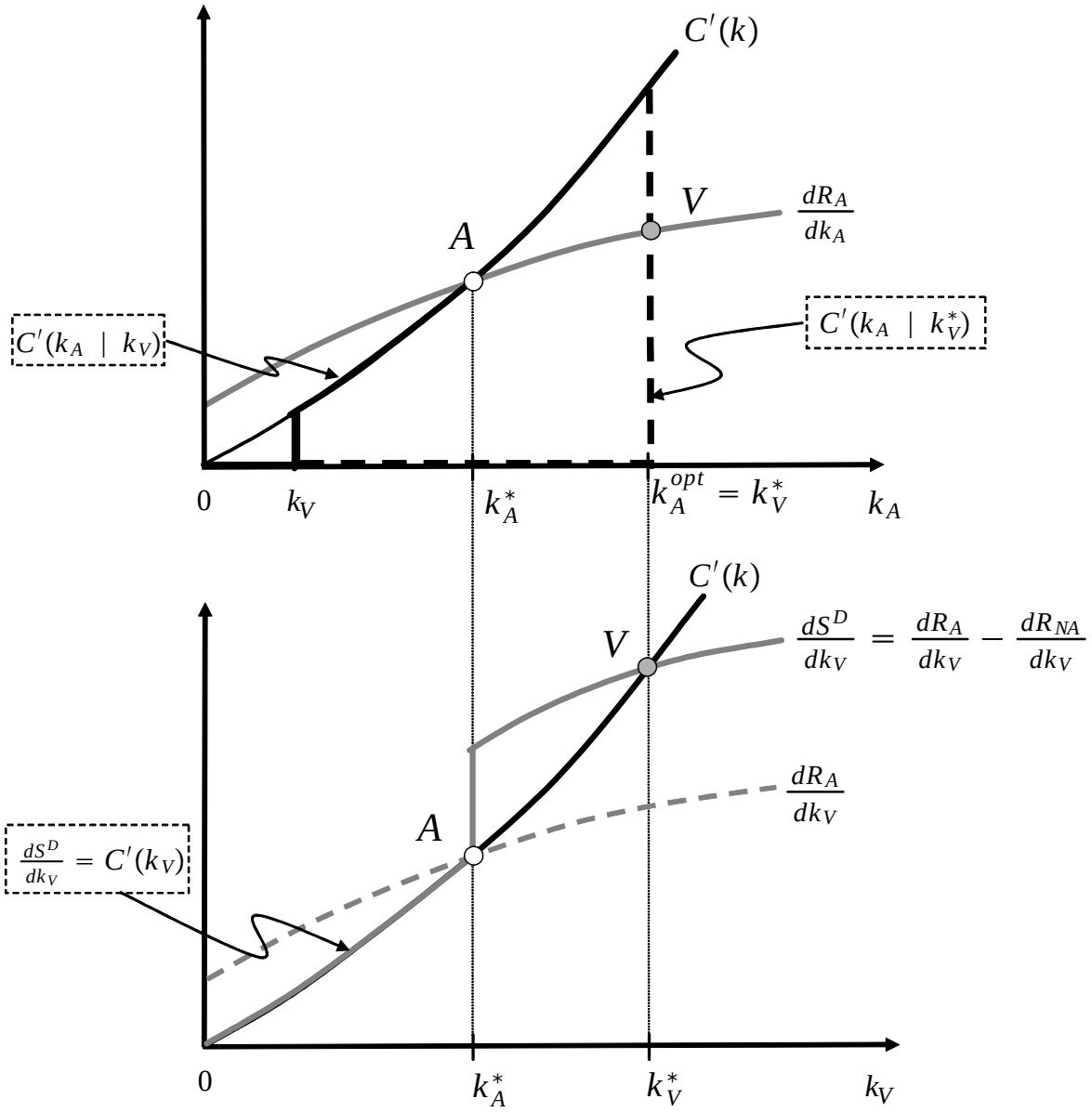

Figure 3.1: Illustrating optimal development by an acquiring incumbent firm and a venture capitalist.

Lemma 1. *In stage 3, the developed innovation is acquired by an incumbent firm, at a price, S^D, equal to a rival incumbent firm's valuation of the developed innovation, i.e. $S^{D^*} = w_{II}$.*

Proof. See Appendix A.1.

3.4. Stage 2: Optimal development by the venture-backed firm

The venture-backed firm invests in development of the basic innovation, thereby maximizing the net sales price of a developed innovation, i.e., $S^D(k_V) - C(k_V)$. To focus on the product market effects, we assume the venture-backed firm and the incumbent firms to face the same variable cost function when investing in development. Using Lemma 1 and (3.8), this problem is then defined as:

$$\underset{\{k_V\}}{Max}: \; S^D(k_V) - C(k_V) \tag{3.9}$$

$$s.t \;:\; S^D(k_V) = \begin{cases} R_A(k_V) - R_{NA}(k_V): & k_A^* \leq k_V \\ R_A(k_A^*) - C(k_A^* \mid k_V) - R_{NA}(k_A^*): & k_A^* > k_V \end{cases} \tag{3.10}$$

$$s.t \;:\; C(k_A^* \mid k_V) = \int_{k_V}^{k_A^*} C'(k)dk.$$

The first line in (3.10) indicates the sales price for a developed innovation when the acquirer only uses the venture capitalist's investment in development without sequential investment, $k_A^{opt} = k_V$, whereas the second line in (3.10) shows the sales price when the acquirer invests $k_A^{opt} - k_V = k_A^* - k_V > 0$ sequentially.

The venture capitalist's maximization problem (3.9) is illustrated in the lower diagram in Figure 3.1. The first-order condition, given that $k_V < k_A^*$, is

$$\frac{dS^D}{dk_V} = C'(k_V): \qquad k_V < k_A^*. \tag{3.11}$$

However, using that $S^D(k_V) = R_A(k_A^*) - C(k_A^* \mid k_V) - R_{NA}(k_A^*)$ for $k_V < k_A^*$ implies that $\frac{dS^D}{dk_V} = \frac{d}{dk_V}\int_{k_V}^{k_A^*} C'(k)dk = C'(k_V)$; consequently, the acquisition price increases by the same amount as the cost of development. Hence, any k_V in this interval will be optimal.

In contrast, if the venture capitalist considers a development choice $k_V > k_A^*$, it maximizes $R_A(k_V) - R_{NA}(k_V) - C(k_V)$ and hence, the first-order condition now becomes:

$$\frac{dS^D}{dk_V} = \frac{dR_A}{dk_V} - \frac{dR_{NA}}{dk_V} = C'(k_V^*) : \qquad k_V > k_A^*, \tag{3.12}$$

where, once more, we assume $C(k)$ to be sufficiently convex so that $R_A(k_V) - R_{NA}(k_V) - C(k_V)$ is strictly concave in k_V. The optimal k_V is indicated as k_V^* in the lower diagram in Figure 3.1. Comparing expressions (3.6) and (3.12), we see that the venture capitalist has stronger incentives to invest in development than the acquiring firm, since the venture capitalist achieves a higher acquisition price by not only taking into account the increase in profits for the acquirer$\frac{dR_A}{dk_V}$, but also by exploiting the negative externalities on the non-acquirer, captured by the last term $\frac{dR_{NA}}{dk_G}$, which is negative from Assumption 1. This is also illustrated in Figure 3.1. From the lower graph, we may note that k_V^* is indeed the global optimum since increasing k_V slightly above k_A^* must increase the net sales price. Turning to the upper graph in Figure 3.1, we note that it is indeed also optimal for the acquiring firm to fully use the venture capitalist investment, i.e. $k_A^{opt} = k_V^*$.

We have the following result:

Proposition 1. *(i) The optimal level of development by a venture-backed firm which resells the developed innovation to an incumbent firm exceeds the optimal level of development by the acquiring incumbent firm, i.e.* $k_V^* > k_A^*$. *(ii) When acquiring a developed innovation through a re-sale from a venture-backed firm, the acquiring incumbent firm performs no further development,* $k_A^{opt} = k_V^*$.

Thus, proposition 1 shows that a venture capitalist has a stronger incentive to develop an innovation than an incumbent firm, since it internalizes the negative effect of development on the non-acquiring firm's profit through the higher acquisition price. Indeed, Zahra (1996) finds that start-ups backed by corporate venture capitalists choose less aggressive strategies than those financed by independent venture capitalists. Moreover, at the aggregate level, venture backed firms, adjusted for size, have been shown to spend

more than twice as much on R&D as non-venture backed firms in the U.S. over the period 1970-2000 (Venture Impact 2004.).

4. The equilibrium ownership of basic innovations and the entrepreneurs' incentives to innovate

We now turn to the question of how the presence of venture capitalists affects the entrepreneur's efforts to produce innovations in stage 0. Once more, we focus on product-market forces as the determinants of the equilibrium innovation pattern by assuming that the entrepreneur sells the basic innovation to the highest bidder at an auction in stage 1. We apply the same acquisition process as in section 3.3 and refer to the description of the game provided in that section. In the auction, incumbent firms' bids are interpreted as direct payments for a full acquisition, while venture capitalists' bids are interpreted as offers of finance and support, in return for a stake in the proceeds of the sale of the developed innovation in stage 3. To simplify, we assume the venture capitalist to obtain the total proceeds of the sale of the venture-backed firm in stage 3.

4.1. Stage 1: The equilibrium ownership of basic innovations

To distinguish stage 1 valuations from stage 3 valuations w, we denote the former by v (omitting subindex). Let us first examine venture capitalists' valuations of the innovation in stage 1. A venture capitalist's stage 1 valuation of the entrepreneur's basic innovation, denoted v_V, is the sales price of the developed innovation gain in stage 3, net the investment costs. Note from Proposition 1 that the optimal behavior in stage 4 upon an acquisition by an incumbent firm is to simply use the venture capitalist's optimal investment without further development, $k_A^{opt} = k_V^*$. From Lemma 1, we then have $S^{D^*} = w_{II}(k_V^*) = R_A(k_V^*) - R_{NA}(k_V^*)$. Thus, we can write the venture capitalist's valuation of the entrepreneur's basic

innovation as:

$$\begin{aligned} v_V &= S^{D^*} - C(k_V^*) \\ &= R_A(k_V^*) - R_{NA}(k_V^*) - C(k_V^*), \end{aligned} \tag{4.1}$$

where it will be convenient to define the associated net gain for a venture capitalist from acquiring the basic innovation at a certain price S^B:

$$\Delta_V(S^B) = v_V - S^B. \tag{4.2}$$

Let us then turn to incumbent firms' valuations. Note from Figure 2.1 that under an incumbent acquisition, we proceed directly from stage 1 to stage 4. In stage 4, the acquiring incumbent firm faces an unconstrained optimization choice of how much to invest in development. The optimal choice k_A^* is then given from equation (3.6). It follows that the stage 1 valuation for an incumbent firm is:

$$v_{II} = R_A(k_A^*) - C(k_A^*) - R_{NA}(k_A^*). \tag{4.3}$$

The valuation v_{II} is thus the value for an incumbent firm of acquiring the basic innovation, when it would otherwise be obtained by a rival incumbent. The associated net gain for an incumbent firm from preempting a rival incumbent acquisition at a certain price S^B is therefore:

$$\Delta_{II}(S^B) = v_{II} - S^B. \tag{4.4}$$

From Proposition 1, we know that if an incumbent acquires the basic innovation, it will be developed to k_A^*, whereas if obtained by a venture capitalist, it will be developed to $k_V^* > k_A^*$. This implies that the profit for an incumbent firm of not obtaining the innovation under a venture ownership of the basic innovation, $R_{NA}(k_V^*)$, differs from the corresponding one when a rival incumbent owns the basic innovation, $R_{NA}(k_A^*)$, since a more developed innovation is here obtained by a rival incumbent firm. Thus, there is a third valuation to consider in this case, v_{IV}, which is the value for an incumbent firm of obtaining the innovation when it would otherwise be obtained by a venture capitalist:

$$v_{IV} = R_A(k_A^*) - C(k_A^*) - R_{NA}(k_V^*), \tag{4.5}$$

with an associated net gain for an incumbent to preempt an acquisition from a venture capitalist at a certain price S^B:

$$\Delta_{IV}(S^B) = v_{IV} - S^B. \tag{4.6}$$

We can then state the following proposition.

Proposition 2. *In stage 1, (i) the valuations of the entrepreneur's basic innovation can be ranked as $v_{IV} > v_V > v_{II}$, which implies that (ii) the basic innovation is acquired by an incumbent firm at a price equal to a venture capitalist's valuation, $S^{B^*} = v_V$.*

Proof. (i) See the text below. A proof for (ii) is given in Appendix A.2. ■

Proposition 2 can be understood as follows:

First, note that the valuation of a venture capitalist exceeds that of an incumbent firm when it considers that a failure to acquire the innovation would imply a direct acquisition by a rival incumbent, i.e. $v_V > v_{II}$. This follows directly from the fact that a venture capitalist maximizes incumbent firms' valuations of the innovation $R_A(k) - R_{NA}(k) - C(k)$ by choosing k_V^* in stage 2 (to resell a developed innovation in stage 3). In contrast, an incumbent maximizes its product market profit $R_A(k) - C(k)$ by choosing k_A^* in stage 4 (upon a direct acquisition in stage 1). Thus, an incumbent firm acquiring the basic innovation paying the price $S^B = v_{II}$ cannot be a Nash-equilibrium, since venture capitalist would gain by bidding higher (i.e. $\Delta_V(v_{II}) = v_V - v_{II} > 0$). Bidding competition among venture capitalists will therefore drive up the price to $S^B = v_V$.

However, an incumbent firm taking the development behavior of a venture-backed firm into account is willing to pay more than a venture capitalist to obtain the innovation, i.e. $v_{IV} > v_V$, since a venture-backed firm would develop the innovation more aggressively in stage 2. To see this, note from Proposition 1 that $k_V^* > k_A^*$ and hence, $v_{IV} - v_V = R_A(k_A^*) - C(k_A^*) - [R_A(k_V^*) - C(k_V^*)] > 0$, since k_A^* maximizes incumbents' net profits $R_A(k) - C(k)$. Thus, a direct acquisition by an incumbent firm avoids such over-investment in development and therefore, an incumbent firm values the basic innovation more highly

than does a venture capitalist. At the price $S^B = v_V$, the acquiring incumbent gains from the acquisition (i.e. $\Delta_{IV}(v_V) = v_{IV} - v_V > 0$), whereas a venture capitalist cannot gain by bidding higher (i.e. $\Delta_V(v_V) = 0$).

Finally, by transitivity, $v_{IV} > v_V > v_{II}$ holds, where the latter inequality implies that rival incumbents will not attempt to outbid an incumbent acquisition (i.e. $\Delta_{II}(v_V) = v_{II} - v_V < 0$).[19] Thus, it follows that the basic innovation is acquired by an incumbent firm investing k_A^* in development, thereby inducing an acquisition price $S^{B^*} = v_V$. This, leads to the following corollary:

Corollary 1. *Incumbents acquire basic innovations to preempt, for them, excessive investments in development that would otherwise be undertaken by venture-backed firms.*

4.2. Stage 0: Equilibrium innovation by the entrepreneur

In stage 0, entrepreneur E undertakes an effort, e, to discover an innovation. Let innovation costs $y(e)$ be an increasing convex function in effort, i.e. $y'(z) > 0$, and $y''(z) > 0$. Let the probability of making an innovation be z and the probability of a failure $1 - z$, where $z \in [0, 1]$ and the probability z is an increasing concave function of effort, i.e. $z'(e) > 0$ and $z''(e) < 0$. $\pi_E = z(e)S^{B^*} - y(e)$ is then the expected net profit of undertaking effort for the entrepreneur, where S^{B^*} is the acquisition price obtained in the auction for the basic innovation in stage 1. The entrepreneur then maximizes π_E, optimally choosing effort e. The optimal effort e^* is given from:

$$\frac{d\pi_E}{de} = z'(e)S^{B^*} - y'(e) = 0, \tag{4.7}$$

with the associated second-order condition, $\frac{d^2\pi_E}{de^2} = z''(e) - y''(e) < 0$.

Applying the implicit function theorem in (4.7), we can state the following Lemma:

[19] From Proposition 1, a venture-backed firm would develop the innovation more aggressively than a rival incumbent firm, $k_V^* > k_A^*$ and hence, $R_{NA}(k_V^*) < R_{NA}(k_A^*)$. Comparing (4.6) and (4.3), the value for an incumbent of preempting a venture capitalist from buying the basic innovation is also higher than preempting a rival incumbent firm, $v_{IV} > v_{II}$.

Lemma 2. *The equilibrium innovative effort by the entrepreneur in stage 0, e^* and hence, the probability of a successful innovation z, increase in the acquisition price obtained in stage 1, S^{B^*}, i.e. $\frac{de^*}{dS^{B^*}} > 0$.*

Having established that entrepreneurial effort in stage 0 is an increasing function of the acquisition price obtained in stage 1, we can now proceed to examine the link between the presence of a venture capitalist market and innovations by entrepreneurs.

As shown in Corollary 1, preemptive acquisitions by incumbents occur in stage 1 to preempt such, for them, excessive investments in development by venture capitalists. However, to obtain the entrepreneur's innovation, the acquiring incumbent firm must at least pay the entrepreneur a price for the innovation matching the venture-backed firm's valuation v_V, which from Proposition 2 exceeds the prevailing price if only incumbents were to bid v_{II}. Then, by using Lemma 2**,** we can state the following Proposition:

Proposition 3. *The presence of venture capitalists increases the acquisition price for basic innovations also in situations where they do not acquire basic innovations. Thus, the presence of venture capitalists increases the level of innovations.*

To highlight the strategic product market effects, we have so far in the analysis assumed that incumbent firms and venture capitalists only differ in objectives but are otherwise symmetric in all other dimensions. But venture capital and incumbent firms are very different types of firms and will likely differ in efficiency when working with different types of tasks. In the next section, we relax the assumption of symmetric efficiency between the two types of firms.

5. Efficiency differences between venture capitalists and incumbents

In this section, we study how efficiency differences between venture capital firms and incumbent firms affect the equilibrium organization of the innovation industry and thereby

the equilibrium innovation and development pattern.

Empirical research on venture capitalists suggests that they possess unique assets in terms of informational advantages, monitoring and control abilities. For instance, Hellmann and Puri (2002) find evidence of US venture capital being related to a variety of professionalizing measures, such as human resource policies, the adoption of stock options plans, and the hiring of a marketing VP. Bottazzi, Da Rin and Hellmann (2004) find similar evidence for European venture capital. Yet, in other situations, incumbent firms will possess advantages due to their larger scale and accumulated knowledge. We capture such efficiency differences in a simple way by assuming venture capitalists and incumbents to differ in fixed costs F_h associated with development, while keeping the assumption that variable costs $C(k)$ are symmetric. Thus, venture capitalists have an advantage in developing innovations whenever $0 \leq F_V < F_I$.

The valuations will now depend on the fixed cost of development for incumbents and venture-backed firms. First, note that fixed costs must be constrained to $F_I \in [0, v_{IV}]$ to have incumbents bidding, and $F_V \in [0, v_V]$ to have venture capitalists bidding, where v_{IV} and v_V are defined in Section 4.1. For such low fixed costs it can be shown that venture-backed firms emerge in equilibrium if and only if $v_{IV} - F_I < v_V - F_V$. The equilibrium ownership is then illustrated in Figure 5.1. In region 4 in Figure 5.1, no sale of the basic innovation occurs. To proceed, define the *Preemption-condition* as combinations of fixed costs such that the incentive for incumbents to preempt venture capitalists from obtaining the basic innovations, $v_{IV} > v_V$, is balanced by a fixed-cost advantage for venture capitalists:

$$\mathcal{F}_I^{PE}(F_V) = \begin{cases} F_V + v_{IV} - v_V; & F_V[0, v_V), \\ v_V; & F_V \geq v_V. \end{cases} . \tag{5.1}$$

Then, define the *VC-condition* $\mathcal{F}_I^{VC}(F_V)$ as combinations of fixed-costs at which a venture capitalist's stronger incentive to aggressively invest in development (to maximize incum-

bents' willingness to pay in stage 3), $v_V > v_{II}$, is balanced by a fixed-cost disadvantage:

$$\mathcal{F}_I^{VC}(F_V) = \begin{cases} 0; & F_V \in [0, v_V - v_{II}) \\ F_V - (v_V - v_{II})\,; & F_V \in [0, v_V - v_{II}) \\ [v_{II}, \infty)\ ; & F_V = v_V \end{cases} \tag{5.2}$$

For relatively high fixed costs for incumbents $F_I \geq \mathcal{F}_I^{PE}$ in Region 1, the Nash-equilibrium involves a venture capitalist buying the basic innovation at price $S^{B^*} = v_V - F_V$ investing k_V^* in development. When fixed costs of incumbent firms and venture capitalists are of similar size, i.e. for $F_I^{VC}(F_V) \leq F_I \leq F_I^{PE}$ in Region 2, an incumbent firm obtains the innovation at $S^{B^*} = v_V - F_V$ investing k_A^* into development. Finally, for relatively high fixed costs for venture capitalists in Region 3, an incumbent will acquire the basic innovation at price $S^B = v_{II} - F_I$, once more investing k_A^* in development.

Then, by making use of Proposition 2, we can state the following result:

Proposition 4. *To be active in equilibrium, venture capitalists must be sufficiently more efficient than incumbent firms in identifying and developing basic innovations into commercialized innovations.*

Proposition 4 provides a possible explanation why venture-backed firms are observed to be more aggressive and more successful in bringing commercialized innovations to the market than incumbent firms. In Figure 5.1, venture-backed firms only appear above the Preemption condition $F_I^{PE}(F_V)$. Thus, venture capitalists must be substantially more efficient to exist in equilibrium, since a marginal advantage (i.e. a combination of fixed costs just above the 45 degree line) is not sufficient, as incumbents will then preempt venture capitalists by acquiring basic innovations.

As stated above empirical research on venture capitalists suggests that they are more efficient in bringing commercialized innovations to the market than incumbent firms. However, it can be conjectured that less skilled venture capitalists would enter the market and reduce this difference in efficiency. One explanation why we still observe venture capital to

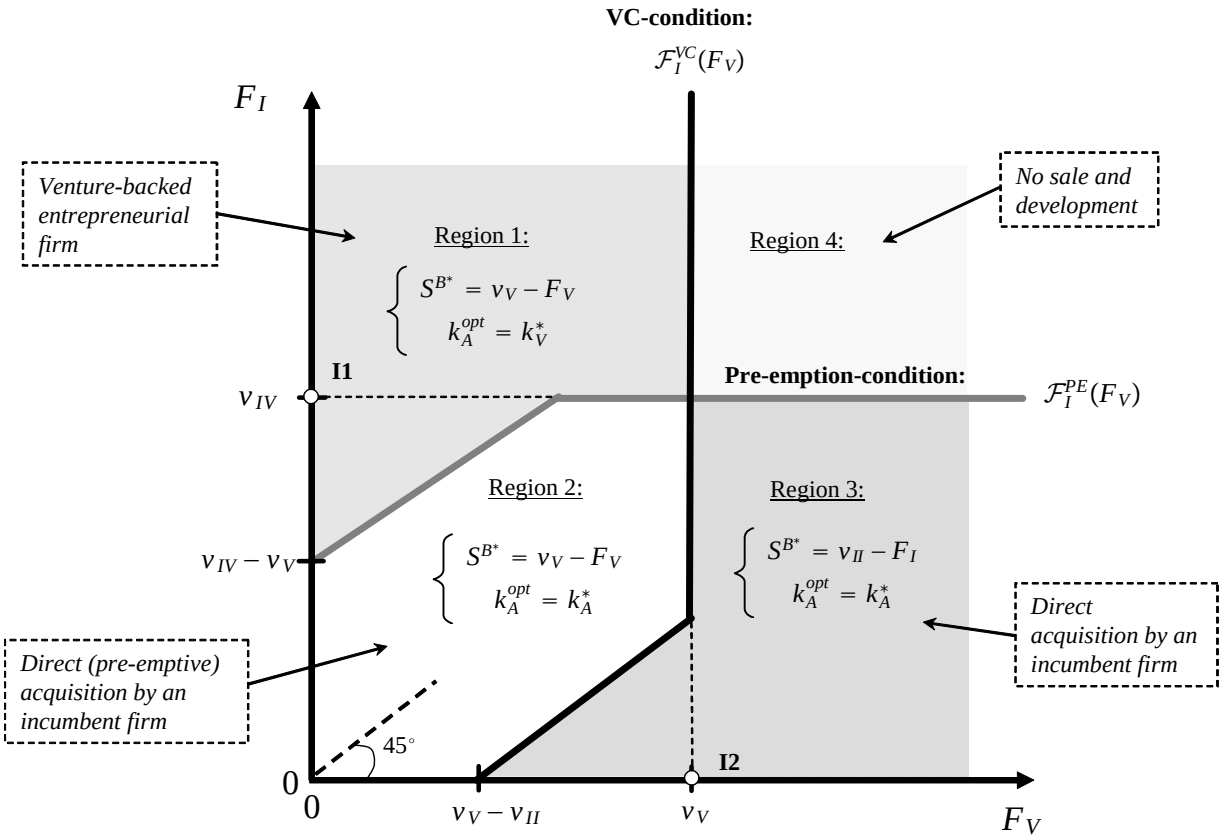

Figure 5.1: The Equilibrium Ownership Structure with fixed cost assymetries.

be more efficient could be that the distribution of skills differs more among risk capitalists. Marginal efficiency, i.e. the least efficient firm, could be the same among venture capitalists and incumbents, while average efficiency would be higher for venture capitalists. Our model instead predicts that not only will venture capital be more efficient on average, but also that marginal efficiency must be higher for venture capitalists.

For simplicity, we have modelled efficiency advantages through the fixed costs. However, the incentives for preemptive acquisitions by incumbents would extend beyond this simple framework. In a more general setting, it follows that venture capital would need to possess substantial advantages in terms of lower variable investments costs, informational advantages, or specific skills to be active in equilibrium.

We can also use this set-up to study the impact of the efficiency level of the venture capital industry on the equilibrium innovation and development levels. It is then possible to derive the following result:

Proposition 5. *(i) The industrial organization with sufficiently inefficient venture capitalists leads to the lowest level of innovations and development, and (ii) the industrial organization with sufficiently efficient venture capitalists leads to the highest level of innovations and development.*

To see this, consider an Industry 1 with $F_V = 0$ and $F_I = v_{IV}$ and an Industry 2 with $F_V = v_V$ and $F_I = 0$. These industries are marked out as I1 and I2 in Figure 5.1, respectively. In stage 1, only venture capital can provide financing for innovations in Industry 1, whereas only direct incumbent acquisitions occur in Industry 2. In each industry, equilibrium fixed costs are zero, i.e. $F^* = 0$, leading to an acquisition price for basic innovations of $S_{I1}^{B^*} = v_V$ in Industry 1 and $S_{I2}^{B^*} = v_{II}$ in Industry 2. Thus, from Propositions 1 and 2(i), it then follows that the industry with venture financing does not only generate a higher acquisition price for basic innovations stimulating more innovations, but also more developed innovations. Once more, this occurs as a venture capitalist internalizes the market rivalry among incumbent firms when investing in development,

since such investments are guided by a maximization of the net acquisition price in the auction of the developed innovation in stage 3.

5.1. Return to investment, efficiency differences and the innovation- and development pattern

In this section, we will study how the importance of the venture capital market for the innovation and development pattern depends on the return to investment and the cost for development of incumbent firms and venture-backed firms, respectively. To this end, we apply a Linear-Quadratic Cournot model (LQC), allowing us to derive explicit solutions for optimal behavior by agents in all stages of the game.[20]

In the LQC model, it is assumed that the product market competition is Cournot-duopoly in homogeneous goods and that firms face a linear demand, $P = a - \frac{Q}{s}$, where a indicates consumer willingness to pay and s denotes market size. We distinguish between two types of incumbent firms: the acquirer of the innovation is denoted by A, whereas the non-acquirer is denoted by NA. The direct product market profit is $\Pi_h = (P - c_h)x_h$, where x_h is the output for a firm of type $h = \{A, NA\}$. Investments in development k are assumed to reduce the acquirer's marginal production cost, i.e. $c_A = c - k_A$. The non-acquirer is assumed to have the marginal cost $c_{NA} = c$. We let $C(k_h) = \frac{\mu k_h^2}{2} + F_h$ be the total investment cost for development faced by venture capitalists (i.e. $h = V$) and an incumbent firm (i.e. $h = A$), respectively. The model is solved backwards. It is straightforward to derive that the optimal Cournot quantities, in stage 5, from (3.1), become $x_A^*(k_h) = s\frac{\Lambda+2k_h}{3}$ and $x_{NA}^*(k_l) = s\frac{\Lambda-k_h}{3}$, where $\Lambda = a - c > 0$ is assumed. Using linear demand, reduced profits are given by $R_A(k_h) = s\left(\frac{\Lambda+2k_h}{3}\right)^2$ and $R_{NA}(k_h) = s\left(\frac{\Lambda-k_h}{3}\right)^2$.

Solving the optimal investment for an acquiring incumbent firm k_A^* (defined) in (3.6) in stage 4 and the optimal investment for the venture capitalist in (3.12) in stage 2, it is

[20] This type of framework, typically modelling an investment game followed by a stage with oligopoly interaction, has been applied in d'Aspremont and Jacquemin (1988), Leahy and Neary (1997) and Neary (2002), for example. A central difference between those papers and our study, is that our application examines the effects of adding an acquisition game.

shown in the Appendix that Proposition 1 holds:

$$k_V^* = \frac{2\eta}{3-2\eta}\Lambda, \quad k_A^* = \frac{4\eta}{9-8\eta}\Lambda, \quad k_V^* - k_A^* = 2\eta\frac{(3-4\eta)}{(3-2\eta)(9-8\eta)}\Lambda > 0, \tag{5.3}$$

where $\eta = \frac{s}{\mu}$ can be interpreted as the relative return to development (increasing in market size s and decreasing in development costs μ).

We now turn to solving the optimal behavior in the acquisition auction games in stage 1. In the Appendix, we derive the valuations v_{IV}, v_{II} and v_V required to solve the auction and which will now depend on the return to investment η. This is illustrated in Figure 5.2(ii), where we first depict the preemption-condition $\mathcal{F}_I^{PE}(\eta) = v_{IV} - v_V + F_V$, which in this setting shows combinations of fixed-costs and the relative return to development η at which the motive for incumbents to preempt venture capitalists from obtaining the basic innovations is balanced by a fixed-cost advantage for venture capitalists. Once more, the second curve is the VC-condition, $F_I^{VC}(\eta) = v_{II} - v_V + F_V$, which shows combinations of fixed costs and return to development η at which a venture capitalist's incentive to aggressively invest in development (to maximize incumbents' willingness to pay in stage 3) is balanced by a fixed-cost disadvantage.

It follows that venture-backed firms emerge in equilibrium if and only if $F_I > F_I^{PE}(\eta)$. Figure 5.2(ii) then illustrates that (a) venture-backed firms emerge in equilibrium when their cost advantages are sufficiently large, and (b) venture-backed firms emerge in equilibrium when the returns to development η are either low or high. In contrast, incumbent acquisitions occur when the return to development is of medium size.

The pattern in Figure 5.2(ii) can be explained from Figure 5.2(i), where we examine how the difference $k_V^* - k_A^*$ behaves when varying the return to development η. Note that investments in development by a venture capitalist k_V^* always exceed investments by an incumbent firm k_A^*, but this difference is inversely U-shaped. When η is close to zero, very little development takes place in either case, which implies that there is less over-investment by venture capitalists and hence, the preemptive motive for incumbents to outbid venture capitalists is weak. This is also the case at a sufficiently large return

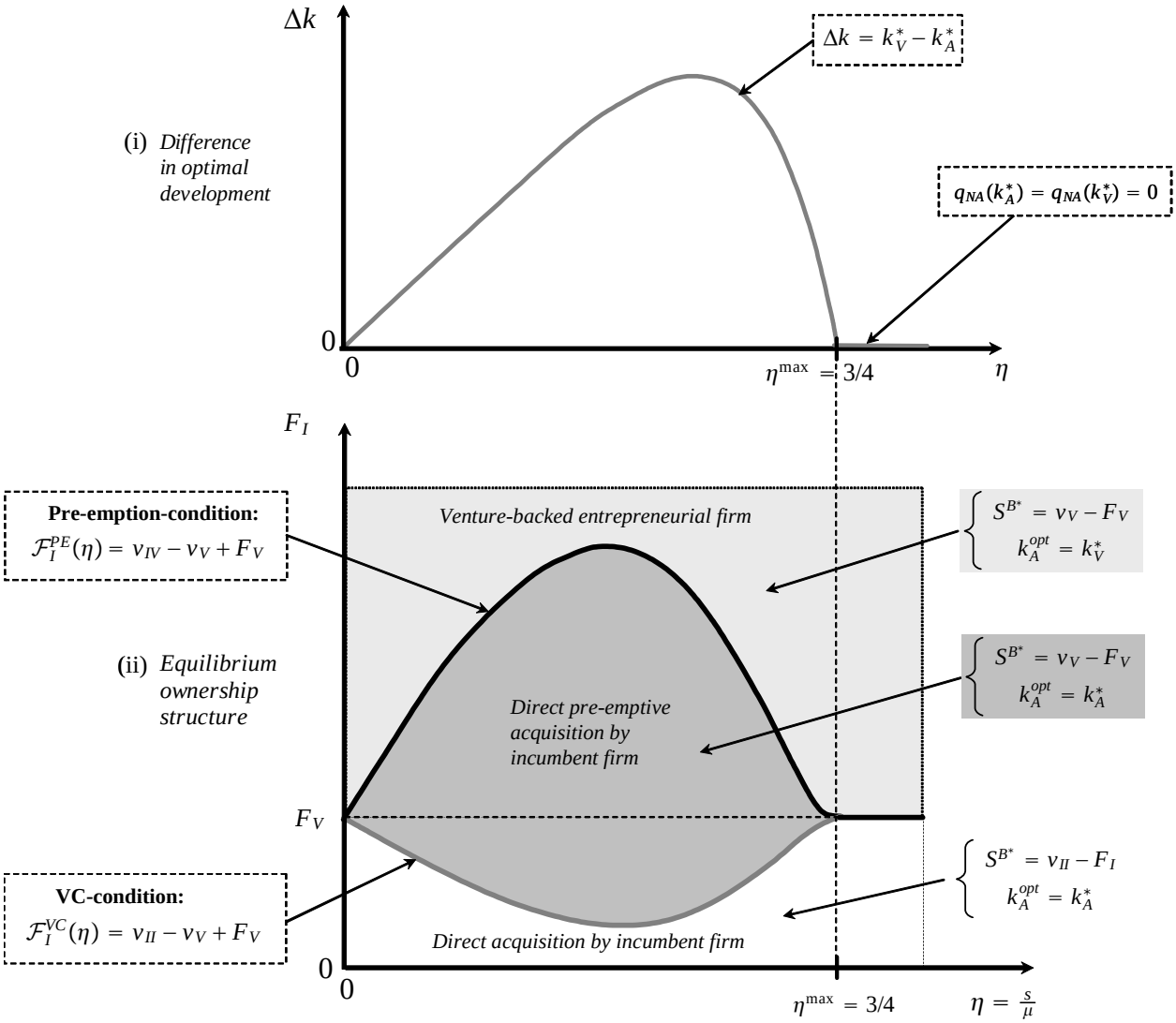

Figure 5.2: Illustrating (i) the difference in optimal development between a venture capitalist and an incumbent firm, (ii) the equilibrium ownership structure (EOS), in the Linear-Quadratic Model.

to development (i.e. close to $\eta^{\max} = 3/4$), since the non-acquiring firm then has a small market share, thereby weakening the strategic motive for over-investment by venture capitalists.[21] Hence, as shown in Figure 5.2(ii), in these regions, small cost advantages for venture capitalists induce venture-backed firms. However, at medium returns to development, market competition is stronger, as is the strategic over-investment from venture capitalists. The preemptive motive for an incumbent firm to obtain the basic innovation is therefore strong and direct acquisitions by incumbent firms take place.

Summing up, we thus have the following result on the equilibrium industrial organization of the innovation industry in the LQM model:

Proposition 6. *In the Linear-Quadratic Model, venture-backed firms emerge in equilibrium when their cost advantages are sufficiently large and the returns to development are either sufficiently low or sufficiently high.*

Finally, let us turn to stage 0 where, from Lemma 2, we know that innovation effort increases in the sales price in the auction in stage 1, S^B. Then, once more, contrast Industry 1 where only venture capital can provide financing for innovations (i.e. $F_V = 0$ and $F_I = v_{IV}$) , to Industry 2 where only direct incumbent acquisitions occur (i.e. $F_V = v_V$ and $F_I = 0$). Again, $S_{\mathrm{I1}}^{B^*} = v_V$ and $S_{\mathrm{I2}}^{B^*} = v_{II}$. In Figure 5.3, we depict the increase in sales price $\Delta S = S_{\mathrm{I1}}^{B^*} - S_{\mathrm{I2}}^{B^*} = v_V - v_{II}$ due to the presence of venture capitalists. Figure 5.3 then illustrates that the sales price difference (and thereby the highest difference in innovation) will be for relatively high levels of returns to investment, but not too high so that one firm becomes too dominant in the market.

[21] This follows directly from (3.12) and (3.6), since comparing the marginal benefit of investing in development for a venture capitalist and an incumbent firm, it can be shown that

$$\frac{dS^D}{dk} - \frac{dR_A}{dk} = \frac{2}{3} x_{NA}^*.$$

That is, the strategic effect on the non-acquirer will be decreasing in this firm's size. In the Appendix, we show that $x_{NA}^* = 0$ for $\eta = 3/4$.

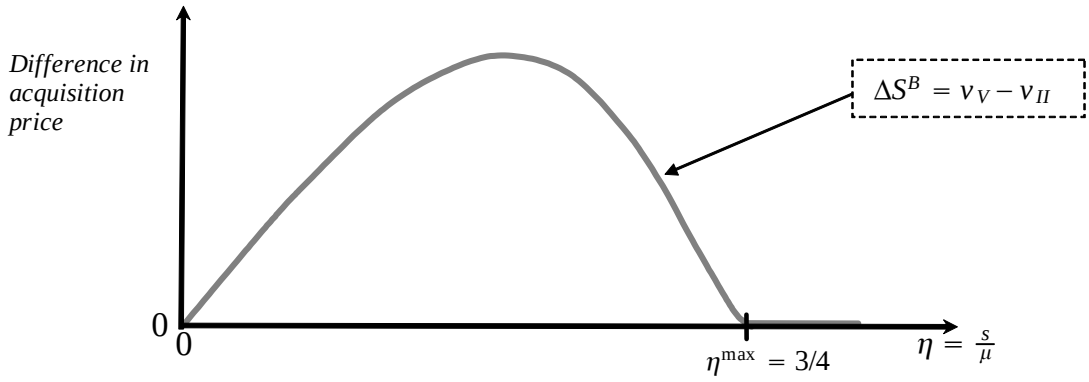

Figure 5.3: Illustrating the effect of venture capital on the acquisition price of basic innovations in the Linear-Quadratic Model.

6. Discussion

The main finding of this paper is that in equilibrium, the venture-backed firm has a stronger incentive to develop the basic innovation than the incumbent, since it internalizes the negative effect of development on the non-acquiring firm's profit through the acquisition price of the venture-backed firm. However, will these incentives remain sufficiently strong also when relaxing some of the assumptions made in the above analysis? In the sections below, we explore the effects of allowing for investment by the non-acquiring incumbents, and different selling procedures of the innovations (venture-backed firm).

6.1. Investments by the non-acquirer incumbents

In the main analysis, we have assumed that only the acquiring venture capitalist or the acquiring incumbent firm spends resources on development. It can be shown that our main results will also hold when investments by non-acquiring incumbent firms are included in the analysis. To see this, consider the situation when the arrival of the basic innovation in stage 1 defines a new consumer market or a new technology into which incumbent firms and venture capitalists may invest. Then, assume that obtaining the basic innovation in stage 1 conveys the possessor – the acquiring incumbent or the acquiring venture capitalist

– with a first-mover advantage over non-acquiring incumbent firms developing this new technology. The idea is that non-acquiring incumbents learn about the new market or technology, but are disadvantaged from not obtaining the innovation. To implement this new setting, we assume that when the game moves to the investment game in development in stage 4, the non-acquiring incumbents act as followers and the acquiring incumbent as "a Stackelberg leader". Otherwise, the timing in Figure 2.1 remains the same. Let demand and costs be the same as in the Linear-Quadratic Cournot model in section 5.1. When the innovation is acquired by an incumbent, k_A^* is determined from (3.6), which now becomes

$$\frac{\partial R_A}{\partial k_A} + \frac{\partial R_A}{\partial k_{NA}} \mathcal{R}'_A(k_A) = C'(k_A),$$

where s $\mathcal{R}_{NA}(k_A)$ is the reaction function for the non-acquiring incumbent, given from that firm's first-order condition $\frac{\partial R_{NA}}{\partial k_{NA}} - C'(k_{NA}) = 0$.

Upon an acquisition of the basic innovation by a venture capitalist, the first-order condition for development in stage 2 in order to sell a developed innovation in stage 3:

$$\frac{dS^D}{dk_V} = \frac{\partial R_A}{\partial k_V} + \frac{\partial R_A}{\partial k_{NA}} \mathcal{R}'_A(k_V) - \frac{dR_{NA}}{dk_V} = C'(k_V).$$

As shown in the Appendix, Proposition 1 holds also when allowing for investments by the non-acquiring incumbents:

$$k_V^* - k_A^* = \frac{2\left(8\eta^2 - 20\eta + 9\right)\eta^3 \Lambda}{(81 - 216\eta + 160\eta^2 - 32\eta^3)(9 - 4\eta)(3 - 4\eta)(3 - 2\eta)} > 0. \tag{6.1}$$

Since it is verified that venture capitalists overinvest in development, it follows from (3.7) that our results also extend into this setting.

6.2. Different selling mechanisms

In the analysis, we have assumed that the seller of the innovation uses a first-price sealed bid auction. We believe that this auction set-up captures essential features of the bidding competition over a scarce asset in situations where acquisitions are used to gain access to innovations, which indeed are frequently used in practice.

But this implies that some possibilities for creating rents are potentially neglected. More generally, Jehiel, Moldovanu and Stacchettis (1996, 1999) show that sophisticated mechanisms are needed to maximize revenues in auctions with externalities where, for instance, it might be the case that all firms in the market need to provide transfers to the seller. However, as pointed out by Jehiel and Moldovanu (2000), a problem with these mechanisms is that the seller needs unrealistically strong commitment power and thus, these mechanisms are often not feasible. Consequently, different types of restricted selling mechanisms that are feasible in a specific application might be studied. One potentially feasible strategy which enables venture-backed firms to extract more rents would be to sell the basic innovation, threatening to aggressively develop the innovation. Assuming away fixed development costs, an incumbent firm would be willing to pay $v_{IV} = R_A(k_A^*) - C(k_A^*) - R_{NA}(k_V^*)$, which would give the venture-backed firm larger proceeds as compared to the case when it develops the innovation and then sells it, since it would then get $w_{II} - C(k_V^*) = R_A(k_V^*) - C(k_V^*) - R_{NA}(k_V^*)$, where $w_{II} - C(k_V^*) < v_{IV}$. The implication of the existence of a venture capital market would then be that it triggers even more basic innovations, but that these are not developed to the same extent.

6.2.1. Exclusivity

In the analysis, we have also assumed that the seller could only sell the innovation exclusively to one buyer. In many cases, when the innovation to a large extent consists of indivisible assets in terms of capital or human capital, such a setting is self evident. However, in some situation, several buyers might hold a licence to utilize the innovations. In such situations, the seller must consider how many licences to sell. This issue is studied in the literature on patent licensing. Kamien and Tauman (1986) assume that the independent innovator acts as a standard monopolist, by positing a price and allowing the buyers to decide whether to buy a licence. Then, they show that the number of licences is falling in the quality of the innovation in such a setting. Allowing the seller to commit to the number of licences to sell, Katz and Shapiro (1986) show that there exists

an equilibrium where some potential buyers are left without a licence. Exclusivity is also studied by Bernheim and Whinston (1998) who use a menu-auction type of set -up where the potential buyers offer contracts to the seller and where the payments in the contract are dependent on whether they get an exclusive right.[22] They show that the equilibrium contract maximizes aggregate surplus and that there exits an equilibrium with exclusive rights. However, they abstract from oligopolistic effects. But applying the findings in Norbäck and Persson (2004, 2005) that aggregate industry profit in Cournot and Bertrand models will be higher if only one firm gets access to a sufficiently drastic cost reduction into the Bernheim and Winston (1998) framework, would imply that exclusivity is also a possible equilibrium outcome in oligopolies and is more likely the more drastic is the innovation. Moreover, Stennek (2005) shows that the seller might choose an exclusive right, even though this does not maximize industry profits in situations where the seller cannot commit to exclusivity. Thus, exclusivity is also a possible outcome in situations where entrepreneurs can sell several licences. The over-investment incentive for the seller identified in the main analysis would then be present also when several licences could be sold.

6.2.2. Resale

We have assumed that the incumbent firm keeps the innovation when acquiring it. It might be the case that after development, it could benefit from reselling to one of its rivals. However, in Norbäck and Persson (2004), we show that in this symmetric set-up, the incumbent firm will be indifferent between selling and keeping the developed innovation. But, in a setting with asymmetric firms, it would not. If there is a sufficiently more efficient owner in the market, a sale is likely to take place. However, it is also likely that it is costly to sell an innovation to a rival firm, due to different types of transaction costs. For instance, it likely that the value for the buyer would decrease, since it is difficult for

[22] The model is closely related to, but not a special case of, the framework of menu auctions developed in Bernheim and Whinston (1986).

the seller to commit to not using its knowledge about the innovation to develop a similar product in the future. In this paper, we therefore assume that the incumbent firm keeps the innovation if acquiring it. Yet, it is interesting to better understand when incumbent firms would keep new innovations and when they would sell them to rival firms. This is an issue left to future research.

6.3. IPOs

Basically all existing literature on venture capital studies exit by IPOs, whereas we study exit by sale to incumbents. What would happen if we allowed both types of exits, i.e. IPOs and sale to incumbents? In principle, the venture-backed firm must then, prior to its choice of development, consider whether it is more profitable to exit by IPO or by a sale to an incumbent. If it is more profitable to exit by a sale to an incumbent, our model set-up is valid. So, when is exit by a sale to an incumbent more profitable? Gans et al. (2002) and Gans and Stern (2003) show that firms are more likely to act as suppliers of technology when intellectual property rights are secure, investment costs are high and brokers facilitating trade are available. When the opposite applies, start-ups are more likely to commercialize their innovations through entry. However, also taking into account product market effects, we expect several other variables to be important for this choice, such as the type of innovation: product or process innovation, drastic and non-drastic innovation, the intensity of product market competition and type and strength of information problems. A study of this issue is left to future research.

7. Conclusions

This paper takes as its starting point that the exit of venture-backed firms often takes place through a sale to a large incumbent firm. We show that in such an environment, venture-backed firms have a stronger incentive to develop basic innovations into commercialized innovations than do incumbent firms, due to strategic product market effects. In turn, this

will increase the price for basic innovations, thereby triggering more basic innovations by entrepreneurs. Consequently, the presence of a venture capital market implies that more basic innovations are created and become better developed.

In the policy debate, it is argued that the acquisition of small innovative companies would weaken the prerequisites for the innovative process by preventing the development of new companies. But our results point in the direction that a well functioning takeover market for small companies would, if anything, facilitate a more rapid industrial development. Established companies can often exploit inventions more efficiently, as they possess company-specific assets, such as a functioning distribution network and production plants. A functioning takeover market with competition for small innovative companies implies that the inventor receives a large share of the value created by his invention, which creates an incentive for innovation.

Moreover, we provide a possible explanation why venture-backed firms are observed to be more successful in bringing commercialized innovations to the market than incumbent firms. Empirical research on venture capitalists suggests that they possess unique assets in terms of informational advantages, monitoring and control abilities and thereby, they are more efficient in bringing commercialized innovations to the market than incumbent firms. However, it might then be believed that less skilled venture capitalists would enter the market and reduce this difference in efficiency. Our model provides an explanation why this might not necessarily be the case. The reason is that in an oligopoly, venture-backed firms will, in equilibrium, produce more development than incumbents due to strategic product market effects. Moreover, we show that to exist in equilibrium, they must be substantially more efficient, otherwise incumbents will preempt venture capitalists entering the market by acquiring basic innovations.

A commonly cited problem for the European economies is the lack of a thriving entrepreneurial sector, not the least as compared to the Anglo-Saxon economies, and that the lack of a well-functioning venture capital market might be one of the important ex-

planations for this phenomenon.[23] The results in this paper suggest that the lack of a well-functioning venture capital market would be most detrimental to the speed of innovation in industries with a high return to investment, since the strategic product market effects would be particularly strong in these types of markets. Consequently, our model predicts that the entrepreneurial sector in Europe should be relatively less successful in serving industries such as high-tech industries, where R&D spending is high and relatively more successful in industries such as textile and restaurants, with low levels of R&D.

Moreover, our model predicts that the less efficient venture capital market in Europe would lead to more preemptive acquisitions by large incumbent firms, leading to lower levels of development of basic innovations in Europe, and thereby a lower return to R&D measured in output.

Conducting a welfare evaluation of the existence of a venture capital market is outside the scope of this paper. However, let us discuss some welfare implications that might indicate some areas of future research. Let us start with consumer surplus effects. The consumer surplus will be at least as high under the industrial organization with as in that without venture capitalists. This follows from Proposition 5, where it was shown that the investment levels will be highest in the industrial organization with venture capitalists. Moreover, it follows from Lemma 2 that the effort level will be higher and thus, the probability of an innovation will increase. Accordingly, the expected consumer surplus will be at least as high in the industrial organization with as in the one without venture capitalists.

Let us now turn to total surplus effects. Here, the analysis becomes more involved since the producer surplus might be reduced when a venture capital market is introduced. To see this, consider the situation where we assume the total cost of the innovation to be equal to the expected gain for the entrepreneur. This implies that no expected surplus is captured by the entrepreneur. It then follows that the introduction of a venture capital market will decrease the expected total producer surplus in the industry, which follows

[23] See Bottazzi and Da Rin (2002) for an assessment of venture capital in Europe.

from the fact that non-acquiring firms' profits decrease in the development level of the innovation and that, in equilibrium, the acquirer's net profit cannot exceed the profit of a non-acquiring firm. Consequently, the expected aggregate producer surplus decreases in this special case. It is left to future research to evaluate these welfare effects in detail.

A. Appendix:

A.1. Proof of Lemma 1

First, consider the equilibrium candidate where incumbent i_w acquires the innovation, denoted $\mathbf{b}^*$. Note that $b^*_{i_w} > v_i - \varepsilon$ is a weakly dominated strategy, since no owner will post a bid over its maximum valuation of obtaining the innovation. If $b^*_{i_w} < v_i - \varepsilon$, firm i_s benefits from deviating to $b^{**}_{i_s} = b^*_{i_w} + \varepsilon$, since it then obtains the innovation and pays a price lower than its valuation of obtaining it. Last, consider candidate $b^*_{i_w} = v_i - \varepsilon$, $b^*_{i_s} = v_j - 2\varepsilon$. Then, no owner has an incentive to deviate. Thus, this is a Nash equilibrium and the only NE where firm i_w obtains the assets.

Second, note that the situation where no incumbent obtains the innovation cannot occur if there is no reservation price at the auction. ■

A.2. Proof of Lemma 2(ii)

Consider the equilibrium candidate where incumbent firm i_w obtains the innovation and where venture capitalist j_s has the second highest bid, denoted b^*. Then, $b^*_{i_w} > v_V$ is not an equilibrium since firm i_w would then benefit from deviating to $b_{i_w} = v_V$ since $b^*_{j_s} < v_V$, otherwise venture capitalist j_s uses a dominated strategy. $b^*_{iw} < v_V - \varepsilon$ is not an equilibrium, since venture capitalist j_w would then benefit from deviating to $b_{j_w} = v_V - \varepsilon$. If $b^*_{i_w} = v_V$ and $b^*_{j_s} = v_V - \varepsilon$, then firm i_w has no incentive to deviate. By deviating to $b'_{i_s} \leq b^*_{i_w}$, firm i_s's, $i_s \neq i_w, i_s$'s payoff does not change. By deviating to $b'_{i_s} > b^*_{i_w}$, firm i_s's payoff decreases, since it must pay a price above its willingness to pay, v_{ii}. Accordingly, firm i_s has no incentive to deviate. Venture capitalist j has no incentive to deviate since $b'_j \geqslant b^*_{i_w}$ is a dominating strategy and the payoff does not change by deviating to $b'_j < b^*_{i_w}$. Thus, b^* is a Nash equilibrium. There is also a similar equilibrium where $b^{**}_{i_w} = v_V - \varepsilon$ and $b^*_{j_s} = v_V - 2\varepsilon$. However, since ε is very small, we treat them as the same equilibrium in the main analysis.

Consider the equilibrium candidate where venture capitalist j_w obtains the innovation,

denoted b^*. First, note that $b^*_{j_w} > v_V - \varepsilon$ is a dominating strategy. Then, note that if $b^*_{j_w} \leq v_V - \varepsilon$, incumbent i_w has an incentive to deviate to $b'_{i_w} = b^*_{j_w} + \varepsilon$ since $v_{IV} > v_V$. This contradicts the assumption that b^* is a Nash Equilibrium. ■

B. The Linear Quadratic Cournot Model

The inverse U-shape of $k^*_V - k^*_A$ in η in Figure 5.2(i) can be shown as follows: First, note from $k^*_V - k^*_A = 2\eta\frac{(3-4\eta)}{(3-2\eta)(9-8\eta)}\Lambda = 0$ at $\eta^{\max} = 0$. From (5.3), $\frac{d}{d\eta}(k^*_V - k^*_A) = 6\Lambda\frac{27-72\eta+40\eta^2}{(3-2\eta)^2(9-8\eta)^2}$ from which it follows that $\frac{d}{d\eta}(k^*_V - k^*_A)|_{\eta=0} > 0$ and $\frac{d}{d\eta}(k^*_V - k^*_A)|_{\eta=3/4} < 0$. Setting $\frac{d}{d\eta}(k^*_V - k^*_A) = 0$, and noting that $k^*_V - k^*_A$ is continuous in η for $\eta < 2/3$, $k^*_V - k^*_A$ has a unique maximum $\eta^* = \frac{9}{10} - \frac{3}{20}\sqrt{6} < 2/3 < 3/4$, where the latter restriction comes from preserving $x_{NA}(k^*_V) \geq 0$ and where $\frac{d^2}{d\eta^2}(k^*_V - k^*_A)|_{\eta=\eta^*} < 0$. Finally, it can be noted that $k^*_V - k^*_A = 2\eta\frac{(3-4\eta)}{(3-2\eta)(9-8\eta)}\Lambda = 0$ at $\eta^{\max} = 3/4$. The acquirer becomes a monopolist and the investment behavior of venture-backed firms and the incumbent firms are then symmetric.

Using $R_A(k_h) = s\left(\frac{\Lambda+2k_h}{3}\right)^2$, $R_{NA}(k_h) = s\left(\frac{\Lambda-k_h}{3}\right)^2$ and (5.3), it can be shown that $v_{II} = R_A(k^*_A) - C(k^*_A) - R_{NA}(k^*_A) = 16s\eta\frac{(1-\eta)}{(9-8\eta)^2}\Lambda^2$, $v_{IV} = R_A(k^*_A) - C(k^*_A) - R_{NA}(k^*_V) = \frac{4s}{9}\eta\frac{(32\eta^2-75\eta+45)}{(3-2\eta)^2(9-8\eta)}\Lambda^2$ and $v_V = R_A(k^*_V) - R_{NA}(k^*_V) - C(k^*_V) = \frac{2s}{3}\eta\frac{1}{(3-2\eta)}\Lambda^2$. Moreover, calculations show that $v_{IV} - v_V = \frac{2s}{9}\eta\frac{(3-4\eta)^2}{(9-8\eta)(3-2\eta)^2}\Lambda^2 > 0$ and $v_{II} - v_V = -\frac{2s}{3}\eta\frac{(3-4\eta)^2}{(9-8\eta)^2(3-2\eta)}\Lambda^2 < 0$. It can be checked that $9 - 8\eta > 0$ holds from the second-order condition associated with (3.6), $3-2\eta > 0$ holds from the second-order condition associated with (3.12) and $3-4\eta > 0$ must be fulfilled to have $x^*_{NA}(k^*_A) = s\dfrac{3-4\eta}{9-8\eta}\Lambda > 0$ and $x^*_{NA}(k^*_V) = s\dfrac{3-4\eta}{9-6\eta}\Lambda > 0$.

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