RESEARCH INSTITUTE OF INDUSTRIAL ECONOMICS

IFN Working Paper No. 783, 2009

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

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December 19, 2008

Abstract

We construct a model where incumbents can either acquire basic innovations from entrepreneurs, or wait and acquire developed innovations from entrepreneurial firms supported by venture capitalists. We show that venture-backed entrepreneurial firms have an incentive to overinvest in development vis à vis incumbents due to strategic product market effects on the sales price of a developed innovation. This will trigger preemptive acquisitions by incumbents, thus increasing the reward for entrepreneurial innovations. We also show that venture capital can emerge in equilibrium if venture capitalists have cost advantages, or if development is associated with double moral hazard problems.

Keywords: Acquisitions, Entrepreneurship, Innovation, Venture Capital

JEL classification: G24, L1, L2, M13, O3

*We have benefitted from useful comments from Daron Acemoglu, Ulf Jakobsson, Rachel Kranton, Kevin Murphy, Søren Bo Nielsen, Jonas Vlachos and participants in seminars at the Research Institute of Industrial Economics (Stockholm), IGIER at Bocconi University, Helsinki Center of Economic Research, CEBR (Copenhagen) and IUI Network: Theory and Practise Workshop (Stockholm). Financial support from the Marianne and Marcus Wallenberg Foundation and Tom Hedelius' and Jan Wallander's Research Foundation is gratefully acknowledged. This paper was written within the Gustaf Douglas Research Program on Entrepreneurship. Email: lars.persson@ifn.se, pehr-johan.norback@ifn.se.

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 raises 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 venture-backed firms often takes place through a sale to 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 the exit mode, except at the beginning of the period. Moreover, according to *The Economist* (1999)[5], 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

[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 option 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. In the biotech industry, Lerner and Merges (1998) note that acquisitions are important for know-how transfers. OECD (2002) argues that established firms often acquire firms to access new technologies.

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

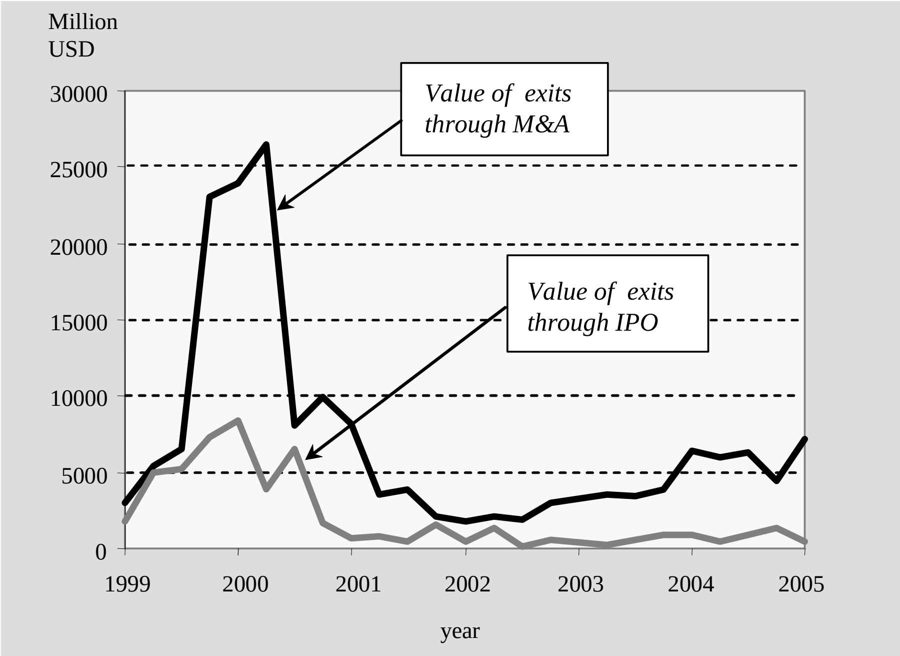

Figure 1.1: The value of exits through M&A and IPO in the US. Source: Thomson Venture Economics/National Venture Capital Association.

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 marketable 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 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.

To this end, we present a model where in the initial stage of the interaction, there is an

[6] An example is Cerent, which was acquired by Cisco at $6.9 billion.

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

entrepreneur investing in an innovative activity that might lead to the creation of a basic innovation, 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. 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.[8] The buyer (incumbent or venture capitalist) will then invest in the development of the innovation, which will increase the possessor's profit, but decrease the profits of the rival incumbents 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 incumbents are the potential buyers. Given the innovation and development pattern, the incumbents compete in oligopoly fashion in the product market in the final stage.

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. 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 exploits the fact that investments in the development of the basic innovation increase 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).

[8] All players in the model are 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 (see Gompers and Lerner (2001) and Kaplan and Strömberg (2001).

Then, we show that when venture capitalists and incumbent firms are equally efficient in developing basic innovations and compete to gain control over these, direct preemptive acquisitions of basic innovations by incumbents occur. Incumbent firms take into account that venture-backed firms will invest more aggressively in development and thus, preempt such, for them, excessive investments in development. However, the presence of venture capitalists, even when not active in equilibrium, will increase the price of basic innovations which, in turn, induces a higher entrepreneurial effort to innovate.

Consequently, to exist in equilibrium, venture capitalists must have some type of advantage. We then proceed by identifying three different reasons why venture capitalist can be active in equilibrium. First, if venture capitalists possess some type of cost advantages, for instance due to a better ability to create incentives for entrepreneurs, they will be able to outbid incumbents in the bidding over basic innovations. Second, incumbents might prefer a late acquisition of a developed innovation to an early preemptive acquisition of a basic innovation, if moral hazard problems are present. The reason is that underinvestment due to a double moral hazard problem in the venture is countered by the above identified overinvestment effect in the venture-backed firm, bringing investments closer to the first-best choice of the acquirer. Third, its is shown that non-acquiring incumbents gain more from a direct preemptive acquisition than the acquiring incumbent. This implies that a coordination failure can emerge between incumbents, and a venture-capitalist might be able to outbid incumbents with a positive probability.

Finally, we show that asymmetries in size across incumbents might reverse the above identified overinvestment result and thus, venture capital will have no effect on equilibrium innovation and development. The reason is that the sales price of the venture-backed firm now depends on the valuation of the firm with the second highest valuation. The venture-backed firm will overinvest with respect to that firm's private optimal investment, but the acquirer might prefer a higher (or lower) development level.

This paper can be seen as a contribution to the literature that studies the properties of the innovation market when innovations can be developed both by incumbents and independent parties. One strand of this literature takes its starting point in the advantage of incumbent-based development relative to independent development being that synergies with existing incumbent assets can be realized, whereas its disadvantages are that less powered incentive schemes can be used in the organization. In such an environment, Amador and Landier (2003) study how the level of potential of the project affects the pattern of independent and incumbent-based development and Anand, Gatetovic and Stein (2004) study how the pattern of independent and incumbent-based development is affected by changes of property rights. Moreover, Gromb and Scarfstein (2002) make use of a labor market model to determine the equilibrium level of independent and incumbent-based development. Another strand of this literature studies how product market effects affect the pattern of independent and incumbent-based development of innovations. Hellmann (2002) studies how the level of complementarity and substitutability between an innovation and an oligopolistic incumbent's assets affects independent and incumbent-based financing. Anton and Yao (1994) study how the competing threats of expropriation by the incumbent and product market entry by the independent innovator affect the division of surplus from the innovation, and Gans and Stern (2000, 2003) extend this approach to study how these forces affect the R&D incentive pattern of incumbents and independent innovators.

We add to the above literature by endogenizing the productivity (size) of the innovation and allow for competitive bidding among the oligopolistic incumbents over the innovation. It is then shown that due to the difference in incentives between the selling independent developer and the incumbent (the former maximizes the net sales price and the latter maximizes net profits), the selling independent developer has an incentive to choose a higher level of productivity of the assets than the incumbent's optimal choice.

This paper is also related to the literature on patent licensing, where licences are sold to potential buyers that are competing in a downstream oligopoly market.[9] [10] Most papers

[9] For an overview, see Kamien (1992). The paper is also related to the literature on the persistence of monopoly; see, for instance, Chen (2000) and Gilbert and Newbery (1982).

[10] This paper could also be seen as a contribution to the literature on auctions with externalities. See, for instance, Jehiel, Moldovanu and Stacchetti (1999) and Jehiel and Moldovanu (2000). We

in this literature treat the size of the innovation as exogenous. To our knowledge, the only exception is Katz and Shapiro (1986) who determine the optimal licensing fee of a research lab which can affect the size of the innovation. They find that the incentive to develop the innovation is decreasing in the number of incumbents owning the research lab. We add to this literature by endogenously determining the ownership of the innovation – before and after its size (or development) is determined – in situations where agents with different characteristics are potential owners.

Finally, this paper can also be seen as a contribution to the literature on entrepreneurship and innovations.[11] We extend this literature by constructing a theoretical model framework where efficiency effects of the interaction among entrepreneurs, venture capitalists and oligopolist in the innovation process can be analyzed.[12]

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 show that venture capital financing may emerge in equilibrium if venture capitalists possess cost advantages, if development is associated with moral hazard problems, and if there are coordination problems among incumbents in the acquisition stage. In Section 6, it is shown that asymmetries across incumbents have the potential to reverse the above identified overinvestment result. In Section 7, empirical implications of the model are discussed. Section 8 concludes the paper.

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add to this literature by endogenizing the productivity of the assets sold in an environment where this productivity can be affected by an ex ante investment of the seller.

[11] For overviews, see Acs and Audretsch (2005) and Bianchi and Henrekson (2005).

[12] Baumol (2004) stresses the importance of the different roles played by small entrepreneurial firms and large established firms in the innovation process in the US, where small entrepreneurial firms create a large share of breakthrough innovations and large established firms provide more routinized R&D.

2. The Model

The model is illustrated in Figure 2.1. We consider an oligopoly industry served by a set $\mathcal{I} = 1, 2, .., i, ..., N_I$ of symmetric firms. 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 $\mathcal{J} = \{1, 2, .., j, .., N_J\}$. The venture capitalists compete to provide expertise and financial support to the entrepreneur 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. Note that ex-ante symmetry implies $k_{V_j} = k_V$. If, on the other hand, an incumbent firm i obtains the innovation in stage 1, the acquiring firm invests k_{A_i} in development in stage 2 where once more, ex-ante symmetry implies $k_{A_i} = k_A$. In stage 3, upon development, 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.[13] Finally, in stage 4, the incumbent firms compete in

[13] It is shown in Norbäck and Persson (2006) that the acquiring firm will never invest sequentially in

oligopoly interaction, setting an action x_i.

3. Venture capitalists and the incentives to develop innovations

3.1. Stage 4: Product-market equilibrium

Using backward induction, we start with the product market interaction, where firm i chooses an action $x_i \in R^+$ to maximize its *direct* product market profit, $\Pi_i(x_i, \mathbf{x}_{-i}, k)$, 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 previously undertaken (by the acquiring incumbent or the venture-backed firm) k, where we omit the subindex in order to avoid heavy notation. We may consider the action x_i as setting a quantity or a price, as will be shown in later sections. We assume that there exists a unique Nash-Equilibrium in actions, $\mathbf{x}^*(k)$, defined from the first-order condition (3.1):

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

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 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, we can define the *reduced-form* product market profits of the acquirer and a non-acquirer as direct functions of k:[14]

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

equilibrium.

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

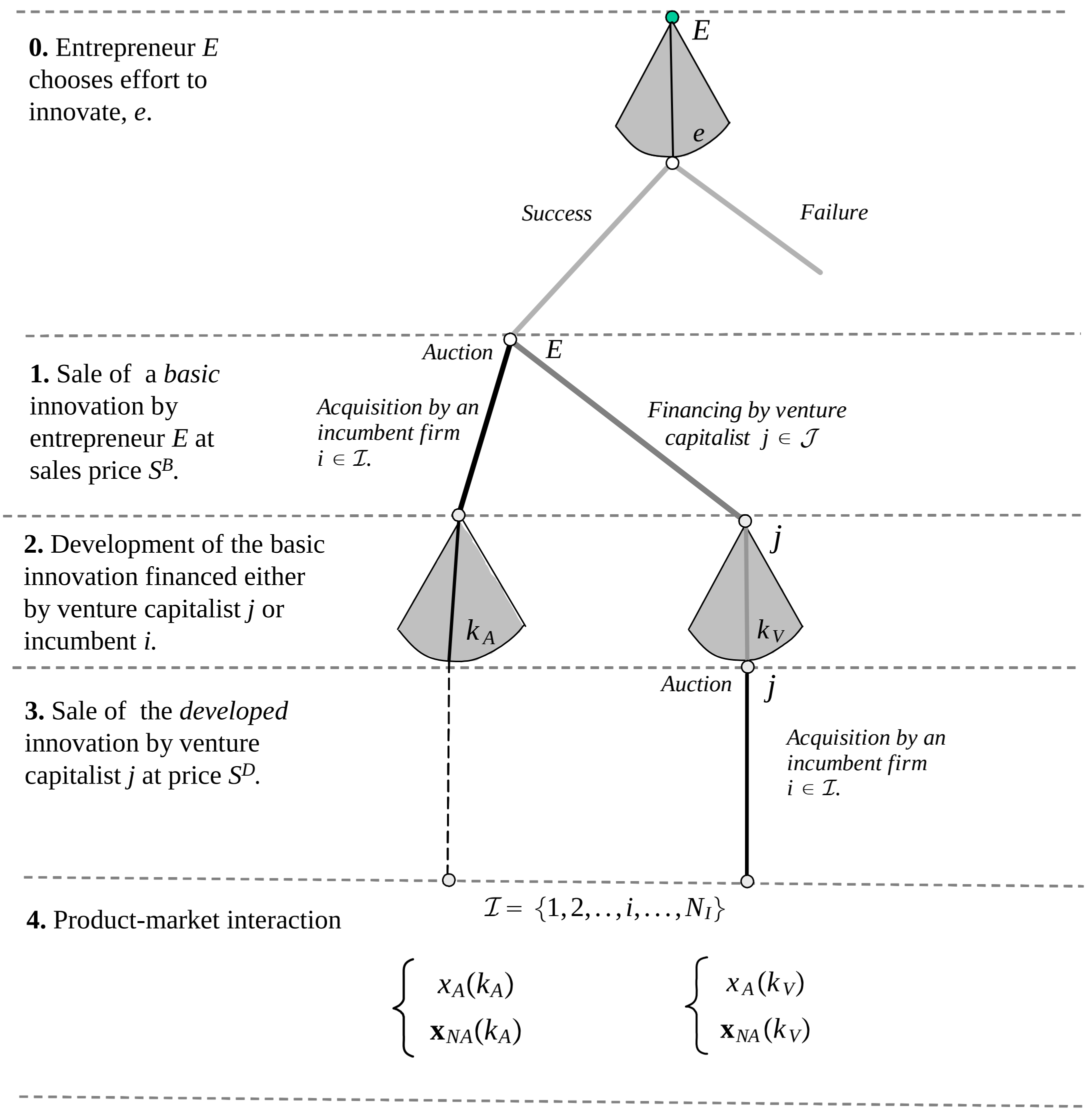

Figure 2.1: The structure of the game.

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

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

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, $\frac{\partial R_A}{\partial k}$ and $\frac{\partial R_{NA}}{\partial k}$, keeping in mind that these summarize the total effects on the product-market profits.[15]

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

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.[16] 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 (3.3), where the first letter in the subscript refers to an incumbent buyer and the second letter to the alternative buyer being another incumbent. 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:

$$w_{II} = R_A(k) - R_{NA}(k). \tag{3.3}$$

[15] Assumption 1 holds in the Linear-Quadratic Cournot model which is presented below, but it is also compatible with other oligopoly models: Farrell and Shapiro (1996).

[16] 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.

Note that since incumbent firms are symmetric ex-ante, their valuations are symmetric. It is then straightforward to derive the following lemma[17]:

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.

3.3. Stage 2: Development of the basic innovation

In subsection 3.3.1, we determine the optimal level of development when an incumbent develops the basic innovation, whereas Section 3.3.2 determines the optimal level of development when the venture backed firm develops the basic innovation.

3.3.1. The acquiring incumbent's optimal development

Assume that the acquirer faces a strictly convex investment cost function, $C(k)$, such that $C'(k) > 0$ and $C''(k) > 0$. Then, the maximization problem facing the acquiring incumbent firm can be written as follows:

$$\underset{\{k\}}{Max} : R_A(k) - C(k), \tag{3.4}$$

where $C(k) = \int_0^k C'(k)dk$ is the total cost of investing k in development and $C'(k)$ is the associated marginal cost.

We assume $R_A(k) - C(k)$ to be strictly concave in k. The optimal choice by the acquiring firm is then defined from the unconstrained optimum condition (3.5):

$$\frac{dR_A}{dk} = C'(k_A^*). \tag{3.5}$$

The optimal investment k_A^* is illustrated in point A in Figure 3.1(i), where the marginal revenue, $\frac{dR_A}{dk}$, equals the marginal cost, C'.

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

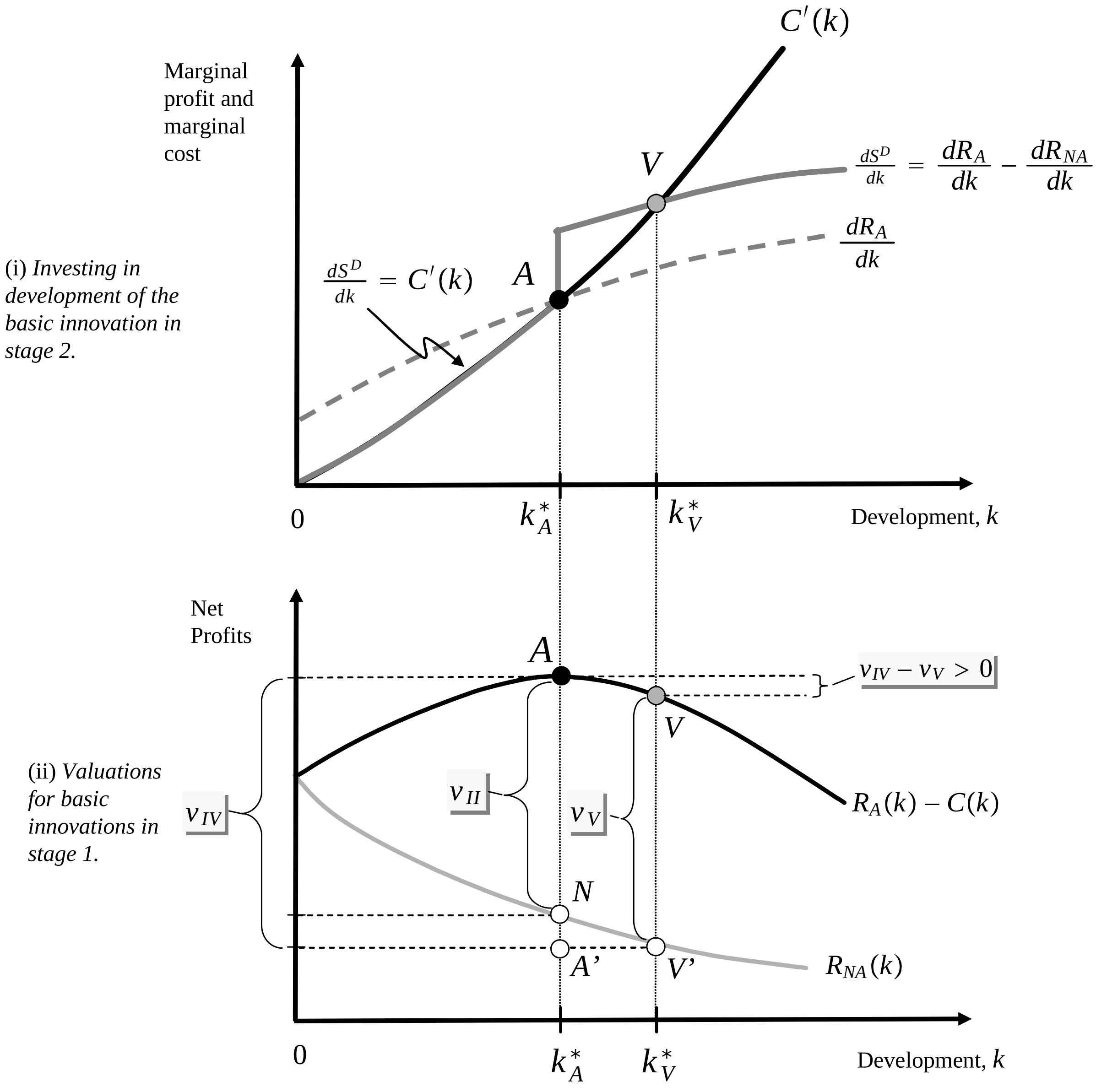

Figure 3.1: Investment incentives and the valuations for basic innovations.

3.3.2. The venture backed firm's optimal development

The venture-backed firm invests in the development of the basic innovation maximizing the net sales price of a developed innovation, i.e., $S^D(k) - C(k)$. We assume the venture-backed firm and the incumbent firms to face the same variable investment cost function $C(k)$ when investing in development. Using Lemma 1 and (3.3), this problem is then defined as:

$$\begin{aligned} \underset{\{k\}}{Max} &: \; S^D(k) - C(k) \\ s.t &: \; S^D(k) = R_A(k) - R_{NA}(k). \end{aligned} \tag{3.6}$$

The first-order condition, is:

$$\frac{dS^D}{dk} = \frac{dR_A}{dk} - \frac{dR_{NA}}{dk} = C'(k_V^*) \tag{3.7}$$

where we assume that $R_A(k) - R_{NA}(k) - C(k)$ is strictly concave in k. The optimal k is indicated as k_V^* in Figure 3.1(i). Comparing expressions (3.5) and (3.7), 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 $\frac{dR_A}{dk}$, but also by exploiting the negative externalities on the non-acquirer, captured by the last term $\frac{dR_{NA}}{dk}$, which is negative from Assumption 1.

Thereby, we have derived the following result:

Proposition 1. *The optimal level of development by a venture-backed firm which sells the developed innovation to an incumbent firm, exceeds the optimal level of development of an incumbent firm, had this firm acquired the innovation prior to its development, i.e.* $k_V^* > k_A^*$.

Thus, proposition 1 shows that a venture capitalist has a stronger incentive to develop an innovation than an incumbent firm, since it exploits the negative effect of development on the non-acquiring firm's profit through the higher acquisition price.

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

We now turn to the equilibrium ownership of basic innovations and the entrepreneurs' incentives to innovate. To this end, we assume 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 3.2 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 financing and support, in return for a stake in the proceeds of the sale of the developed innovation 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. We now derive and rank these stage 1 valuations to solve for the equilibrium ownership and acquisition price for the basic innovation.

First, the valuation v_{II} is the value for an incumbent firm of acquiring the basic innovation, when it would otherwise be obtained by a *rival* incumbent:

$$v_{II} = R_A(k_A^*) - C(k_A^*) - R_{NA}(k_A^*). \tag{4.1}$$

Thus, v_{II} is the difference in the net profit $R_A(k) - C(k)$ of the acquirer and the profit of the non-acquirer $R_{NA}(k)$, evaluated at the acquiring incumbent's optimal development, k_A^* from (3.5). v_{II} is given as the vertical distance between points A and N in Figure 3.1(ii).

Second, a venture capitalist's stage 1 valuation of the basic innovation, denoted v_V, is the sales price of the developed innovation in stage 3, net the investment costs. From Lemma 1, we have $S^{D^*} = w_{II}(k_V^*) = R_A(k_V^*) - R_{NA}(k_V^*)$ and thus, the *venture capitalist's valuation* of the entrepreneur's basic innovation is:

$$\begin{aligned} v_V &= S^{D^*} - C(k_V^*) \\ &= R_A(k_V^*) - C(k_V^*) - R_{NA}(k_V^*). \end{aligned} \tag{4.2}$$

Since a venture capitalist maximizes the net value of incumbent firms' valuations of the innovation $R_A(k) - C(k) - R_{NA}(k)$, the valuation of a venture capitalist must exceed that of an incumbent firm, when it considers that a rival incumbent would otherwise obtain the innovation, $v_V > v_{II}$. This is illustrated in Figure 3.1(ii), where v_V is shown as the vertical distance between V and V'.

Third, if a venture capitalist does obtain the basic innovation, it will be more aggressively developed, $k_V^* > k_A^*$. This implies that the profit for an incumbent firm of *not* obtaining the innovation under a venture ownership of the basic innovation, $R_{NA}(k_V^*)$, will be lower than from the corresponding one when a rival incumbent owns the basic innovation, $R_{NA}(k_A^*)$. Therefore, there is a third valuation to consider, v_{IV}, which is the value for an incumbent firm of obtaining the innovation when it would otherwise be obtained by a venture capitalist:

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

The valuation v_{IV} is also shown in Figure 3.1(ii). As illustrated by the figure, an incumbent is willing to pay more than a venture capitalist to obtain the innovation, in order to avoid an overinvestment by the venture capitalist, $v_{IV} > v_V$. This follows from $v_{IV} - v_V = R_A(k_A^*) - C(k_A^*) - [R_A(k_V^*) - C(k_V^*)] > 0$ since $k_A^* < k_V^*$ maximizes the acquiring incumbent's net profits $R_A(k) - C(k)$.

Thus, we have established the following ranking of valuations:

$$v_{IV} > v_V > v_{II}. \tag{4.4}$$

Using (4.4) we can derive the equilibrium ownership of the basic innovation:[18]

Proposition 2. *In stage 1, the basic innovation is acquired by an incumbent firm at a price equal to a venture capitalist's valuation,* $S^{B^*} = v_V$.

[18] Norbäck and Persson (2006) provide a detailed proof. Note that there exist many such asymmetric equilibria, i.e. as many as there are incumbents.

The unique Nash equilibrium is that where one of the incumbents acquires the basic innovation at a price $S^{B^*} = v_V$. To see why, first note that bidding competition among the symmetric venture capitalists implies that the equilibrium price cannot be lower than $S^B = v_V$. No venture capitalist has an incentive to bid higher. Therefore, let us consider the equilibrium candidate where one incumbent bids v_V and the second highest bid is made by a venture capitalist who bids $v_v - \varepsilon$.

The acquiring incumbent will not deviate to a lower bid. To see why, compare the acquiring incumbent's product market profit net of development costs and acquisition price in an acquisition in stage 1, $\pi_A^1 = R_A(k_A^*) - C(k_A^*) - v_V$, to the net profit this firm would obtain from an acquisition of venture developed innovation in stage 3, $\pi_A^3 = R_A(k_V^*) - S^{D^*} = R_{NA}(k_V^*)$. Using (4.4), we have:

$$\begin{aligned}\pi_A^1 - \pi_A^3 &= R_A(k_A^*) - C(k_A^*) - \underbrace{[S^{D^*} - C(k_V^*)]}_{S^{B^*}=v_V} - \underbrace{[R_A(k_V^*) - S^{D^*}]}_{\pi_A^3} \\ &= R_A(k_A^*) - C(k_A^*) - [R_A(k_V^*) - C(k_V^*)] \qquad (4.5) \\ &= v_{IV} - v_V > 0.\end{aligned}$$

The first line in (4.5) shows that an incumbent always "pays" for a developed innovation – either in a direct acquisition of the basic innovation outbidding the venture capitalists in stage 1, or in the bidding competition with rivals over a developed innovation in stage 3. The second and third line in (4.5) then reveal that the benefit from a direct acquisition comes from avoiding the excessive investments by a venture capitalist which would otherwise occur under a late acquisition. Finally, other incumbents will 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 $R_{NA}(k_A^*) = R_A(k_A^*) - C(k_A^*) - v_{II} > R_A(k_A^*) - C(k_A^*) - v_V = \pi_A^1$ holds from (4.4).

The basic innovation is thus acquired by an incumbent firm investing k_A^* in development, thereby inducing an acquisition price $S^{B^*} = v_V$. Thus, 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 effort e to discover an innovation. Assume that the probability of succeeding with an innovation is the effort, i.e. $e \in [0, 1]$, and that e can be privately chosen by the entrepreneur at an increasing and convex cost $y(e)$, $y'(e) > 0$, and $y''(e) > 0$. $\pi_E = eS^{B^*} - y(e)$ 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^* defined as:

$$\frac{d\pi_E}{de} = S^{B^*} - y'(e^*) = 0, \tag{4.6}$$

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

Applying the implicit function theorem in (4.6), we can state the following Lemma:

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

As shown, 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 bid v_{II}. Then, 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 venture capitalists do not acquire basic innovations. Thus, the presence of venture capitalists increases the rents appropriated by entrepreneurs, and thereby the incentive to innovate.*

5. Venture capitalists in equilibrium

The previous section shows that the development of basic innovations will not be financed by venture capitalists in equilibrium. In this section, we will show that venture capitalist-backed development of basic innovations can emerge in equilibrium when: (i) venture capitalists possess cost advantages, (ii) development of the innovation is associated with moral hazard problems, and (iii) there are coordination problems among incumbents in the bidding over the basic innovation.

5.1. Cost differences between venture capitalists and incumbents

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. Adding fixed development costs, the valuations in (4.1)-(4.3) change to $v_{II} = R_A(k_A^*) - C(k_A^*) - F_I - R_{NA}(k_A^*)$, $v_V = R_A(k_V^*) - R_{NA}(k_V^*) - C(k_V^*) - F_V$ and $v_{IV} = R_A(k_A^*) - C(k_A^*) - F_I - R_{NA}(k_V^*)$, where the optimal investments in (3.5) and (3.7) remain unchanged.[19]

To solve for the equilibrium financing of the entrepreneur's basic innovation, we can proceed as in Section 4.1. Adding fixed development costs to (4.5), the difference in profits of a direct acquisition in stage 1 and a "late" acquisition in stage 3 becomes:

$$\pi_A^1 - \pi_A^3 = R_A(k_A^*) - C(k_A^*) - F_I - [R_A(k_V^*) - C(k_V^*) - F_V]. \qquad (5.1)$$

[19] Note that these fixed cost are taken after the bidding competition has taken place.

The "auction mechanism" will once more select the ownership and the subsequent development of the entrepreneur's basic innovation that maximize the acquiring incumbent's net profit. In (4.5), we noted that incumbent ownership emerges due to overinvestment by venture capitalists. In (5.1), lower development costs for venture capitalists $F_V < F_I$ can compensate for the lower net profit from overinvestment and venture financing can then emerge in equilibrium. Define the fixed cost difference $D = F_I - F_V$ and assume that there exists a $\bar{D} = \bar{F}_I - \bar{F}_V > 0$ which fulfills $\pi_A^1 - \pi_A^3 = 0$. Then, if the development cost were to decrease further for the venture capitalist, the venture capitalist would finance the development of the basic innovation in equilibrium.

We can thus state the following result:

Proposition 4. *To be active in equilibrium, venture capitalists must face a sufficiently lower fixed cost than incumbent firms in developing basic innovations.*

We can also use this set-up to study the impact of the cost efficiency level of the venture capital industry on the equilibrium innovation and development levels. To this end, consider a situation where no venture capital is present, and only incumbents are sufficiently efficient to acquire innovations. Consequently, an incumbent will acquire the basic innovation at price $S^B = v_{II}$, investing k_A^* in development. Then, assume that a sufficiently efficient venture capital market emerges. This implies that we move to the equilibrium where a venture capitalist will acquire the basic innovation at price $S^B = v_V$, investing k_V^* in development. It then follows that the emergence of a venture capital market does not only generate a higher acquisition price for basic innovations, $v_V > v_{II}$, stimulating more innovations, it also induces better developed innovations, since $k_V^* > k_A^*$.

On a final note, it has been acknowledged in the literature that entrepreneurs often put a high value on controlling the development of their initial innovation, and that the entrepreneurs' control rights would be larger when financed by a venture capitalist, than when acquired by an incumbent. This would then imply that the entrepreneur could seek support from the venture capitalist, even though the incumbent is willing to pay more in monetary terms.

5.2. Simultaneous investment

So far, we have assumed all investments in development to be performed by the venture capitalist or the incumbent firm. However, in practice, also the entrepreneur would often need to invest in development. As shown in recent work on venture capital, this can lead to under-investments due to a double moral hazard problem.[20]

To incorporate these features into our framework, we introduce simultaneous investments in stage 2 of the game. Let $K_l = k_l + k_{El}$ then be the total amount of development. Thus, if a venture-backed firm is formed ($l = V$), the entrepreneur and the venture capitalist simultaneously supply non-contractible investments, k_{EV} and k_V, into development. Analogously, if the development takes place within the incumbent firm ($l = A$), the entrepreneur and the acquirer simultaneously supply non-contractible investments, k_{EA} and k_A. Moreover, all agents are assumed to face the same investment cost function $C(k)$. In stage 1, we assume that venture capitalists and incumbents make bids in terms of simple equity-finance contracts $\{\alpha_l, B_l\}$ for $l = V, A$. $\alpha_l \in [0,1]$ specifies the equity share of the proceeds to the venture capitalist or the acquiring incumbent of the joint venture, respectively, and B_l is the price for this equity share. Other parts of the game remain unchanged.

5.2.1. Stage 4: Product-market equilibrium

Let $\Pi_h(x_h, \mathbf{x}_{-h}, K)$ denote the direct product market profit of an incumbent firm of type $h = A, NA$. The optimal market actions $\mathbf{x}^*$ are not affected by the equity contract other than through its impact on total development, K. Reduced-form product market profits are then $R_A(K) \equiv \Pi_A(x_A^*(K), \mathbf{x}_{NA}^*(K), K)$ and $R_{NA}(K) \equiv \Pi_{NA}(\mathbf{x}_{NA}^*(K), x_A^*(K))$, where Assumption 1 holds in total development K, i.e. $\frac{dR_A}{dK} > 0$ and $\frac{dR_{NA}}{dK} < 0$.

[20] See Casamatta (2004), Hellmann (2006), Inderst and Mueller (2004), Repullo and Suarez (2004) and Schmidt (2003).

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

The incumbent firms' valuations of obtaining a developed innovation from a venture capitalist are $w_{II} = R_A(K) - R_{NA}(K)$, which is the price paid by an incumbent in equilibrium, i.e. $S^{D^*} = w_{II}$.

5.2.3. Stage 2: Development of the basic innovation

Let us now determine the optimal development of a basic innovation for a given equity contract, $\{\alpha, B\}$. Start with the case with incumbent financing. Assuming the incumbent's net profit $\alpha R_A(K_A) - C(k_A)$ to be strictly concave in k_A, and the entrepreneur's net profit $(1-\alpha) R_A(K_A) - C(k_{EA})$ to be strictly concave in k_{EA}, the optimal development under incumbent financing $K_A^*(\alpha) = k_A^*(\alpha) + k_{EA}^*(\alpha)$ is given from the Nash-equilibrium (5.2):

$$\begin{cases} \alpha \frac{dR_A}{dK} = C'(k_A^*(\alpha)) \\ (1-\alpha) \frac{dR_A}{dK} = C'(k_{EA}^*(\alpha)). \end{cases} \tag{5.2}$$

Likewise, assuming that the venture capitalist's net sales price $\alpha[R_A(K_V) - R_{NA}(K_V)] - C(k_A)$ is strictly concave in k_V and that the entrepreneur's net sales price $(1-\alpha)[R_A(K_V) - R_{NA}(K_V) - C(k_{EV})]$ is strictly concave in k_{EV}, the optimal development $K_V^*(\alpha) = k_V^*(\alpha) + k_{EV}^*(\alpha)$ under venture financing is given from the Nash-equilibrium (5.3):

$$\begin{cases} \alpha \left[\frac{dR_A}{dK} - \frac{dR_{NA}}{dK}\right] = C(k_V^*(\alpha)) \\ (1-\alpha) \left[\frac{dR_A}{dK} - \frac{dR_{NA}}{dK}\right] = C(k_{EV}^*(\alpha)). \end{cases} \tag{5.3}$$

For a given equity contract, (5.2) and (5.3) imply an incentive for strategic overinvestment under venture financing, $K_V^*(\alpha) = k_V^*(\alpha) + k_{EV}^*(\alpha) > K_A^*(\alpha) = k_A^*(\alpha) + k_{EA}^*(\alpha)$. Yet again, this occurs since the entrepreneur and the venture capitalist achieve a higher acquisition price by not only taking into account the increase in profits for the acquirer, but also by exploiting the negative externalities on the non-acquirer. We now turn to the equilibrium equity contract.

5.2.4. Stage 1: The equilibrium ownership of basic innovations

Let us first derive the equity contract offered by a venture capitalist, $(\alpha_V^*, B_V(\alpha_V^*))$. The bidding competition among venture capitalists implies that a venture capitalist will offer the equity price $B_V(\alpha) = \alpha S^{D^*}(K_V^*(\alpha)) - C(k_V^*(\alpha))$, claiming the equity share $\alpha_V^* = \arg\max_\alpha \left\{S^{D^*}(K_V^*(\alpha)) - C(k_{EV}^*(\alpha)) - C(k_V^*(\alpha))\right\}$. This contract $(\alpha_V^*, B_V(\alpha_V^*))$ will then maximize the gain of the entrepreneur $(1-\alpha)\, S^{D^*}(K_V^*(\alpha)) - C(k_{EV}^*(\alpha)) + B_V(\alpha)$, leaving the venture capitalist at a zero gain.

Let us then turn to the equity contract offered by an incumbent, $(\alpha_A^*, B_A(\alpha_A^*))$. For a given equity share α, an incumbent must at least offer the equity price:

$$B_A(\alpha) = \underbrace{S^{D^*}(\alpha_V^*)) - C(k_{EV}^*(\alpha_V^*)) - C(k_V^*(\alpha_V^*))}_{E's \text{ gain from accepting the VC contract}} - \underbrace{[(1-\alpha)R_A(K_A^*(\alpha)) - C(k_{EA}^*(\alpha))]}_{E's \text{ net profit under incumbent financing}}. \tag{5.4}$$

The price of equity $B_A(\alpha)$ leaves the entrepreneur (E) indifferent between the contract offered by a venture capitalist and the incumbent's contract. The incumbent will then offer the equity contract $(\alpha_A^*, B_A(\alpha_A^*))$, where the optimal equity share maximizes her gain, i.e. $\alpha_A^* = \arg\max_\alpha\{\alpha R_A(K_A^*(\alpha)) - C(k_A^*(\alpha)) - B_A(\alpha)\}$, where $B_A(\alpha)$ is given from (5.4).

We can now proceed as in Section 4.1 to determine the equilibrium ownership of the entrepreneur's basic innovation. Then, let $\pi_A^1 = \alpha_A^* R_A(K_A^*(\alpha_A^*)) - C(k_A^*(\alpha_A^*)) - B_A(\alpha_A^*)$ be the net profit from a direct acquisition in stage 1, and let $\pi_A^3 = R_A(K_V^*(\alpha_V^*)) - S^{D^*}(\alpha_V^*))$ be the net profit of this firm under a late acquisition of a developed innovation in stage 3. Using (5.4), an incumbent's incentive for a direct preemptive acquisition of the basic innovation can then be written:

$$\begin{aligned}
\pi_A^1 - \pi_A^3 &= R_A(K_A^*(\alpha_A^*)) - C(k_A^*(\alpha_A^*)) - C(k_{EA}^*(\alpha_A^*)) - \\
&\quad \left[S^{D^*}(\alpha_V^*)) - C(k_{EV}^*(\alpha_V^*)) - C(k_V^*(\alpha_V^*))\right] - \qquad (5.5)\\
&\quad \underbrace{[R_A(K_V^*(\alpha_V^*)) - S^{D^*}(\alpha_V^*))]}_{\pi_A^3} \\
&= R_A(K_A^*(\alpha_A^*)) - C(k_{EA}^*(\alpha_A^*)) - C(k_A^*(\alpha_A^*)) - \qquad (5.6)\\
&\quad [R_A(K_V^*(\alpha_V^*)) - C(k_{EV}^*(\alpha_V^*)) - C(k_V^*(\alpha_V^*))].
\end{aligned}$$

In (5.5), we note that the term $S^{D^*}(\alpha_V^*))$ appears both in the second and third line. Thus, an incumbent will pay for a *developed* innovation regardless of when the acquisition takes place. From (5.6), this implies that the incentive for an early preemptive acquisition is, yet again, given by the difference in the product market profit of the acquiring incumbent net of investment costs, evaluated at the investments arising from an early and a late acquisition $K_A^*(\alpha_A^*)$ and $K_V^*(\alpha_V^*)$, respectively.[21] We can then state the following result, which is proven below.

Proposition 5. *When investments into development cannot be contracted, the development of the basic innovation may be financed by venture capital in equilibrium*

To see why venture capital may finance development in this setting, it is useful to first derive the acquirer's first-best investment levels $K_A^{opt} = k_A^{opt} + k_{EA}^{opt}$ as a benchmark:

$$\begin{cases} \frac{dR_A}{dK} = C'(k_A^{opt}) \\ \frac{dR_A}{dK} = C'(k_{EA}^{opt}) \end{cases}, \tag{5.7}$$

where we note that since the incumbent and the entrepreneur face identical strictly convex investment costs, $C(k)$, (5.7) implies symmetric investments, $k_A^{opt} = k_{EA}^{opt}$.

We can then compare the benchmark first-best investments K_A^{opt} to the investments in the incumbent firm $K_A^*(\alpha_A^*) = k_A^*(\alpha_A^*) + k_{EA}^*(\alpha_A^*)$ and the venture backed firm $K_V^*(\alpha_V^*) = k_V^*(\alpha_V^*) + k_{EV}^*(\alpha_V^*)$.

It is straightforward to show that regardless of the source of financing of the basic innovation, the optimal equity share involves an equal split for the parties, i.e. $\alpha^* = \alpha_A^* = \alpha_V^* = 1/2$. Thus, investments are symmetric in (5.2) and (5.3), i.e. $k_A^*(\alpha^*) = k_{EA}^*(\alpha^*)$ and $k_V^*(\alpha^*) = k_{EV}^*(\alpha^*)$. It then follows that $K_A^*(\alpha_A^*) < K_A^{opt}$. That is, under the equity contract, (5.2) implies an under-investment problem since the entrepreneur and

[21] Other incumbents will not challenge a rival acquisition in stage 1. From (5.5), we have $\pi_A^1 = R_A(K_A^*(\alpha_A^*)) - C(k_A^*(\alpha_A^*)) - C(k_{EA}^*(\alpha_A^*)) - [R_A(K_V^*(\alpha_V^*)) - C(k_{EV}^*(\alpha_V^*)) - C(k_V^*(\alpha_V^*))] + R_{NA}(K_V^*(\alpha_V^*))$. The net profit for a non-acquiring incumbent under a direct acquisition is $R_{NA}(K_A^*(\alpha_A^*))$. $\pi_A^1 - R_{NA}(K_V^*(\alpha_V^*)) < 0$ then follows since $\alpha_V^* = \arg\max_\alpha \left\{S^{D^*}(K_V^*(\alpha)) - C(k_{EV}^*(\alpha)) - C(k_V^*(\alpha))\right\}$.

the incumbent only take into account their share of the increase in profits when investing, while ignoring the positive effect on the collaborator in the firm.

From (5.2) and (5.3), it also follows that $K_V^*(\alpha^*) > K_A^*(\alpha^*)$. That is, aggregate investments in the venture-backed firm will be larger than in the incumbent firm. The reason is yet again that the venture backed firm maximizes the sales price of a developed innovation. But then, the more aggressive investments under venture financing $K_V^*(\alpha^*) > K_A^*(\alpha^*)$ can compensate for the underinvestment induced by the double-moral hazard problem in the incumbent firm $K_A^*(\alpha^*) < K_A^{opt}$, bringing equilibrium investments closer to the first-best level K_A^{opt}.

Whether incumbent- or venture-financed development of the basic innovation will occur in equilibrium will depend on the details of the model. To show that double moral hazard problems can induce venture capital financing in equilibrium, we apply an example.

The Linear-Quadratic Cournot model (LQC) *Product market competition in stage 4 is a Cournot-duopoly in homogeneous goods with linear demand,* $P = a - \frac{Q}{s}$*, where* a *indicates consumer willingness to pay and* s *denotes market size. Direct product market profits are* $\Pi_h = (P - c_h)x_h$ *, where* x_h *is output for a firm of type* $h = \{A, NA\}$*. The marginal cost of the acquirer is* $c_A = c - [k_A + k_{EA}]$ *under direct acquisition by an incumbent, and* $c_A = c - [k_V + k_{EV}]$ *when development is undertaken by the venture-backed firm. The non-acquirer is assumed to have the marginal cost* $c_{NA} = c$*. Reduced-form profits in (3.2) then take the form* $R_h = \frac{1}{s}(q_h^*)^2$*, where* $q_h^* = s\frac{a-2c_h+c_{-h}}{3}$*. The total investment cost for development faced by each type of investor,* $h = A, V$ *is* $C(k_h) = \frac{\mu k_h^2}{2}$ *and* $C(k_{Eh}) = \frac{\mu k_{Eh}^2}{2}$*, where* $\mu > 0$ *is a cost parameter such that (omitting subindex)* $C'(k) = \mu k$ *and* $C''(k) = \mu$*. We can then derive the following lemma.*

Lemma 3. *In the LQC model with simultaneous investments: (i)* $\alpha_A^* = \alpha_V^* = 1/2$*, (ii) a venture capitalist will finance the development of the entrepreneur's basic innovation under the contract* $\{\alpha_V^* = \frac{1}{2}, B_V^* = \frac{1}{2}[R_A(K_V^*(\alpha_V^*)) - R_{NA}(K_V^*(\alpha_V^*))] - C(k_V^*(\alpha_V^*))\}$ *and, (iii) aggregate investments fulfill* $K_A^{opt} > K_V^*(\alpha_A^*) > K_A^*(\alpha_V^*)$*.*

Proof. See the Appendix. ■

Consequently, we have shown that incumbents may abstain from early preemptive acquisitions of basic innovations if they face double moral hazard problems in investments, since venture-backed firms' overinvestment brings investments closer to the acquirer's first-best investments. In Norbäck and Persson (2006), it is also shown that when efficiency differences between the entrepreneur and the venture capitalist (incumbent) are introduced, the equity contract will award the more efficient party a larger share of the proceeds of the venture. This will limit the double moral hazard problem and preemptive acquisitions by incumbent firms will then dominate in equilibrium as in Section 4.

5.3. Coordination failures among incumbents

We now turn to a third mechanism through which venture capital can be active in equilibrium. We use the benchmark model of Section 4 to spell out the argument. From the proof of Proposition 2, it follows that the gains of a direct preemptive acquisition of the basic innovation in stage 1 are unevenly distributed among incumbents. The acquiring incumbent bears the cost of the preemption, while the other incumbents free-ride:

$$R_{NA}(k_A^*) > \pi_A^1 > R_{NA}(k_V^*). \tag{5.8}$$

Since non-acquiring incumbents gain more from a direct acquisition than the acquiring incumbent, a coordination failure between incumbents can emerge. Venture capitalists might then be able to outbid the incumbents acquiring the basic innovation, even though $v_{IV} > v_V$. This can be shown by extending the auction in stage 1 by allowing for mixed strategy equilibria. In such a mixed strategy equilibrium, incumbents can play v_V with a certain probability ρ^* and abstain from bidding with a certain probability $1-\rho^*$, whereas venture capitalists play $v_V - \varepsilon$ with certainty. There are two types of outcomes. In the first, at least one of the incumbents is drawn to make a bid v_V and thus, a direct preemptive acquisition takes place. In the second, all incumbents' bids are drawn as no bidding. In this case, one of the venture capitalists obtains the innovation at price $v_V - \varepsilon$.

Consequently, the coordination failure could be another explanation why venture-backed firms appear in equilibrium, despite the fact that the incumbents would like to preempt venture financing.

6. Underinvestment in venture-backed firms with asymmetric incumbents

We have shown that venture capitalists will overinvest in development in order to extract a high sales price for developed innovations. In this extension, we show that venture capitalists may not overinvest when incumbents are sufficiently asymmetric. The reason is that the sales price of the venture-backed firm now depends on the valuation of the firm with the second highest valuation.

To see why, consider once more the LQC model and assume that the industry contains a low cost incumbent (L) and a high cost incumbent (H). Let $i, j = \{L, H\}$ denote the firm index. The reduced-form profits for firm i when firm j has obtained the developed innovation are $R_{ij} = \frac{1}{s}\left(q_{ij}^*\right)^2$, where $q_{ij}^* = s\frac{a-2c_{ij}+c_{-ij}}{3}$. Let $c_{ij} = \bar{c}_i$ for $i \neq j$ and $c_{ii} = \bar{c}_i - \theta_i k$ be the marginal cost for i when not possessing the innovation and possessing the innovation, respectively. To capture ex-ante differences, we assume that $\bar{c}_L < \bar{c}_H$. Explicit expressions for q_{ij}^* are given in (A.5) in the Appendix, where we also give the proofs for the statements below.

Note that firm i's valuation in stage 3 for a developed innovation in (3.3) is $w_{ij} = R_{ii} - R_{ij}$ for $i \neq j$. Differentiation of w_{ij} in k yields:

$$\frac{dw_{LH}}{dk} = R'_{LL} - R'_{LH} = \frac{4}{3}\theta_L q_{LL}^* + \frac{1}{3}\theta_H q_{LH}^* \tag{6.1}$$

$$\frac{dw_{HL}}{dk} = R'_{HH} - R'_{HL} = \frac{4}{3}\theta_H q_{HH}^* + \frac{1}{3}\theta_L q_{HL}^*. \tag{6.2}$$

If the low cost and the high cost firm are equally efficient in using the developed innovation, $\theta_L = \theta_H = \theta$, the low cost firm will have a higher valuation, $w_{LH} > w_{HL}$. To see this, first note that the increase in profit induced from developing the innovation affects more units in the low cost (larger) firm when this firm obtains the innovation, $q^*_{LL} > q^*_{HH}$. At the same time, the loss in profit as a non-acquirer is more severe for the low cost (larger) firm, since the reduction in profit also affects more units, $q^*_{LH} > q^*_{HL}$. Thus, $\frac{dw_{LH}}{dk} > \frac{dw_{HL}}{dk}$ will hold for a positive development level k. Since, by definition, $w_{LH} = w_{HL} = 0$ at $k = 0$, we have $w_{LH} > w_{HL}$ for $k > 0$.

We can now discuss overinvestment in this setting. Applying Lemma 1, the acquisition price in stage 1 will be $S^{B^*} = w_{HL}$. A venture capitalist will therefore invest to maximize the net valuation of the high-cost firm, $k^*_V = \arg\max_k\{R_{HH}(k) - R_{HL}(k) - C(k)\}$, while the optimal investment under a direct acquisition by the low cost firm maximizes this firm's net profit, $k^*_A = \arg\max_k\{R_{LL}(k) - C(k)\}$. It follows that the difference in the incentive to invest between the large incumbent and the venture capitalist is:

$$R'_{LL} - (R'_{HH} - R'_{HL}) = \frac{\theta}{3}[4(q^*_{LL} - q^*_{HH}) - q^*_{HL}]. \tag{6.3}$$

In the Appendix, we show that if the ex-ante difference in marginal costs $\bar{c}_S - \bar{c}_L > 0$ of the two firms is sufficiently large, $R'_{LL} - (R'_{HH} - R'_{HL}) > 0$ holds in (6.3) and the investment made under a direct acquisition by the low-cost incumbent will be larger than the investment made by the venture capitalist, $k^*_A > k^*_V$. The large low-cost firm then has a stronger incentive to invest to maximize profits, since a given profit increase affects more units, $q^*_{LL} > q^*_{HH}$. At the same time, the negative externality on the high cost firm, which is driving the over-investment effect under venture financing, is limited due to the high cost of the small size firm, q^*_{HL}. Even though the venture capitalist will be maximizing the small firm's valuation, driving investments beyond what is required for profit maximization in this firm, the investment may still be smaller than the profit maximizing investment choice of the large firm.

7. Empirical implications

Kortum and Lerner (2000) find that the presence of venture capitalists significantly increases the patenting rates in US-industries, noting that while the size of venture capital is less than 3 % of corporate R&D outlays, venture capital accounts for about 8 % of the industrial innovations. Our model predicts such an efficiency effect of venture capital.[22]

First, venture capitalists develop innovations more aggressively, since the sales price of an innovation – rather than the product market profit – is maximized. Second, since part of the increase in the sales price is generated by exploiting the negative externalities on non-acquiring incumbents, venture capitalists also need to be more efficient to exist in equilibrium.

Let us now discuss some additional testable implications of the model. One way of testing the over-investment effect would be to directly compare firm level data on development k_V^* and k_A^* (or the associated costs $C(k_V^*)$ and $C(k_A^*)$) for innovations held by venture-backed firms and incumbent firms, respectively. The overinvestment should then be identified in concentrated markets where incumbents are not too asymmetric.

Due to the problem of measurement and availability of detailed data, an alternative method would be to use stockmarket data to indirectly test the over-investment effect. The stock market predictions will, of course, be sensitive to how and when the information about the progress and potential of the venture reaches the stockmarket. Keeping this in mind, assume that the stock market is efficient and values firms according to their expected profits. Moreover, assume that the innovation and development process proceeds as in the game in Figure 2.1. To highlight the effect of the emergence of venture-backed firms, then assume that the outcome of the acquisition game in stage 1 will come as partial surprise for the stock market. This may be due other costs associated with the development of the basic innovation stage 1 which are not perfectly known, or that coordination problems arise between incumbents in preempting venture capitalists.

Under these assumptions, the model would predict that the stockmarket value of incumbents would decrease around the announcement of the signing of a contract between

[22]As stated in the introduction, there are other possible explanations for this empirical result based on information problems, including a sample selection bias associated with firms' self-selection or the screening role of venture capitalists.

an entrepreneur and a venture capitalist for an important venture early in its development process. This would be due to the fact that the stockmarket then foresees a more aggressive development of the innovation than previously expected, which will hurt incumbents in the subsequent acquisition process and product market interaction.

Moreover, if an incumbent acquisition occurs, and the identity of the buyer comes as a partial surprise for the stock market, a second prediction would be that the stockmarket value of the non-acquiring incumbents would increase around the time of the announcement, relative to the acquiring incumbent's stock market value, since outsiders free ride on the acquisition. However, the announcement of an incumbent acquisition of an innovation already extensively developed with venture capital should not affect stockmarket values, since the information on overinvestment is already capitalized in the market.

8. Conclusions

The exit of venture-backed firms often takes place through a sale to an incumbent oligopolistic firm. 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 on the sales price of the venture-backed firm. In turn, this will increase the price for basic innovations, thereby triggering more basic innovations by entrepreneurs.

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 than incumbent firms in bringing commercialized innovations to the market. 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 for why this might not necessarily be the case. The reason is that when innovations are used in oligopolistic markets, venture-backed firms will produce more development than incumbents due to strategic product market effects. This implies that to exist in equilibrium, venture capitalists must be substantially more efficient than incumbents, otherwise incumbents will preempt venture capitalists by acquiring basic innovations.

Our results thus provide additional support for the policy view that a well-functioning venture capital market will increase the innovative activity in a country.[23] Moreover, our results indicate that the importance of the presence of a venture capital market for innovation activity may be underestimated in empirical work. To see this, note that the presence of venture capitalists as potential independent developers, even if they do not develop innovations in equilibrium, still increases the reward and hence, the incentives for entrepreneurial innovations,

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 are indeed frequently used in practice. But this implies that some possibilities for creating additional rents are potentially neglected. More generally, Jehiel, Moldovanu and Stacchettis (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 an unrealistically strong commitment power and thus, they are often not feasible.[24] Nevertheless, if more sophisticated selling mechanisms were to allocate a larger

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

[24] One potentially feasible strategy which makes it possible for the entrepreneur to extract more rents is to sell the basic innovation, threatening to aggressively develop the innovation. In terms of the benchmark model in Section 5, an incumbent firm would be willing to pay v_{IV}, which would give the entrepreneur larger proceeds as compared to the case when it sells directly, since $S^{B^*} = v_V < v_{IV}$. One way of achieving this would be through stating a reservation price at v_{IV}. But this will create problems unless the entrepreneur can develop the innovation herself. To see this, if the reservation price is $v_{IV} > v_V$, venture capitalists might not want to participate in the auction and the threat of over development might not be credible. Thus, the maximum willingness to pay for incumbents would then be v_{II} and the entrepreneur would then be forced to charge a lower reservation price than v_{IV}.

share of the surplus to the entrepreneur, the existence of a venture capital market would trigger even more basic innovations. The additional payment would also be higher in cases where the entrepreneur could develop the innovation herself.

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 $b^*_{i_w} > w_{II} - \varepsilon$ is a weakly dominated strategy, since no owner will post a bid over its maximum valuation of obtaining the innovation. If $b^*_{i_w} < w_{II} - \varepsilon$, 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 $b^*_{i_w} = w_{II} - \varepsilon$, $b^*_{i_s} = w_{II} - 2\varepsilon$. 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 3

From (5.7) we have:

$$k_A^{opt} = k_{EA}^{opt} = 4\tfrac{\Lambda}{9\mu-16}, \tag{A.1}$$

where it can be shown that $9\mu - 16 > 0$ needs to be fulfilled in order to have a unique solution to (5.7). That is, for $9\mu - 16 > 0$ the Hessian to $R_A(K_h) - C(k_h) - C(k_{Eh})$ is negative definite. Formally, we make the assumption:

Assumption A1: $9\mu - 16 > 0$.

From the FOCs in (5.2), the investments in the incumbent firm are:

$$k_A^*(\alpha_1) = k_{EA}^*(\alpha) = 4\alpha\tfrac{\Lambda}{9\mu-8}, \quad k_{EA}^*(\alpha) = 4\left(1-\alpha\right)\tfrac{\Lambda}{9\mu-8} \tag{A.2}$$

where $\Lambda = a - c$. From Assumption A1, it is straightforward to show that (A.2) is a unique, stable Nash-equilibrium.

From the FOCs in (5.3), we obtain the investments in the venture backed firms:

$$k_V^*(\alpha) = 2\alpha \tfrac{\Lambda}{3\mu-2}, \qquad k_{EV}^*(\alpha) = 2(1-\alpha)\tfrac{\Lambda}{3\mu-2}. \tag{A.3}$$

Once more, from Assumption A1, it is straightforward to show that (A.3) is a unique, stable Nash-equilibrium.

Part (i): The optimal equity share Using (A.2), straightforward calculations then show that $\alpha_A^* = \arg\max_\alpha\{\alpha R_A(K_A^*(\alpha)) - C(k_A^*(\alpha)) - B_A(\alpha)\} = 1/2$. Furthermore, from (A.3) direct calculations give $\alpha_V^* = \arg\max_\alpha \left\{S^{D^*}(K_V^*(\alpha)) - C(k_{EV}^*(\alpha)) - C(k_V^*(\alpha))\right\} = 1/2$. The SOC for the optimal equity contract for the incumbent α_A^* is $-32\mu\frac{\Lambda^2}{(9\mu-8)^2} < 0$, whereas the SOC for the optimal equity contract for the venture capitalist α_V^* is $-8\mu\frac{\Lambda^2}{(3\mu-2)^2} < 0$. Thus, $\alpha_A^* = \alpha_V^* = 1/2$ are unique. In the remainder of the proof, we use the short-hand $\alpha^* = \alpha_A^* = \alpha_V^* = 1/2$.

Part (ii): Ownership of the basic innovation From (5.6), preemptive acquisitions of the basic innovation by an incumbent occur iff $\pi_A^1 - \pi_A^3 > 0$. Then, by calculation $R_A(K_A^*(\alpha^*)) - C(k_{EA}^*(\alpha^*)) - C(k_A^*(\alpha^*)) = \mu\Lambda^2\frac{9\mu-4}{(9\mu-8)^2}$, whereas $R_A(K_V^*(\alpha_V^*)) - C(k_{EA}^*(\alpha_V^*)) - C(k_V^*(\alpha_V^*)) = \frac{1}{9}\Lambda^2\frac{4+3\mu+9\mu^2}{(3\mu-2)^2}$. It follows that:

$$\pi_A^1 - \pi_A^3 = \frac{1}{9}\Lambda^2(3\mu-4)\tfrac{64-81\mu^2-12\mu}{(9\mu-8)^2(3\mu-2)^2} < 0. \tag{A.4}$$

From Assumption A1, it follows that $9\mu - 8 > 0$, $3\mu - 4 > 0$ and $64 - 81\mu^2 - 12\mu < 0$ are fulfilled. Thus, $\pi_A^1 - \pi_A^3 < 0$.[25]

[25] $\pi_A^1 - \pi_A^3 < 0$ may hold also when relaxing Assumption A1. For $\mu \in (8/9, 16/9)$, $R_A(K) - C(k) - C(k)$ is strictly convex in k, where $\mu > 8/9$ is required from the SOC associated with the incumbent's investment in (5.2), $9\mu - 8\alpha > 0$, where $\alpha \in [0,1]$. For $\mu > 16/9$, $R_A(K) - C(k) - C(k)$ is strictly concave in k as illustrated in Figure **??**.

Part (iii): Aggregate investments From (A.2)-(A.1), $K_V^*(\alpha^*) = 2\frac{\Lambda}{3\mu-2}$, $K_A^*(\alpha^*) = 4\frac{\Lambda}{9\mu-8}$ and $K_A^{opt} = 8\frac{\Lambda}{9\mu-16}$. Then, by calculation, $K_V^*(\alpha^*) - K_A^*(\alpha^*) = 2\Lambda\frac{3\mu-4}{(3\mu-2)(9\mu-8)} > 0$ and $K_A^{opt} - K_V^*(\alpha^*) = 2\Lambda\frac{3\mu+8}{(9\mu-16)(3\mu-2)} > 0$ holds from assumption A1.

A.3. Overinvestment with asymmetric incumbents

Applying the Linear-Quadratic Cournot (LQC) model described in Section 6 to the FOC in (3.1), we obtain:

$$q_{LL}^* = s\frac{a+2\theta_L k+\bar{c}_S-\bar{c}_L}{3},\ q_{SS}^* = s\frac{a+2\theta_S k+\bar{c}_L-\bar{c}_S}{3},\ q_{LS}^* = s\frac{a-\theta_S k+\bar{c}_S-\bar{c}_L}{3},\ q_{SL}^* = s\frac{a-\theta_L k+\bar{c}_L-\bar{c}_S}{3}. \tag{A.5}$$

From (A.5), we note that $q_{LL}^* > q_{SS}^*$ and $q_{LS}^* > q_{SL}^*$ hold when $\theta_S = \theta_L$ under the assumption $\bar{c}_S - \bar{c}_L > 0$.

Moreover, $k_V^* = \arg\max_k w_{SL}(k) - C(k)$ and $k_L^* = \arg\max_k R_{LL}(k) - C(k)$. Thus, $k_V^* = k_L^*$ holds if $R'_{LL} = w'_{SL} = R'_{SS} - R'_{SL}$. From (6.1)-(6.2), we have $R'_{LL} = \frac{4}{3}\theta_L q_{LL}^*$ and $R'_{SS} - R'_{SL} = \frac{4}{3}\theta_S q_{SS}^* + \frac{1}{3}\theta_L q_{SL}^*$. Substituting (A.5) into these expressions and solving for the critical ex-ante difference $\Delta c = \bar{c}_S - \bar{c}_L$ for which $R'_{LL} = R'_{SS} - R'_{SL}$, we obtain:

$$\Delta c = \frac{(4\theta_S - 3\theta_L)a + \left(8\theta_S^2 - 9\theta_L^2\right)k}{4\theta_S + 5\theta_L}. \tag{A.6}$$

In the case where $\theta_S = \theta_L = \theta$, $\Delta c = \frac{a-\theta k}{9} > 0$. We then have underinvestment in the venture-backed firm ($k_V^* < k_L^*$) if the ex-ante cost difference is sufficiently large, $\bar{c}_S - \bar{c}_L > \Delta c$, but overinvestment ($k_V^* > k_L^*$) if the ex-ante cost differences are sufficiently low, $0 < \bar{c}_S - \bar{c}_L < \Delta c$. Finally, note that if there is an ex-post advantage of the smaller firm $\theta_S > \theta_L$, an even larger ex-ante difference Δc is required to generate underinvestment in the venture-backed firm.

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