Venture Capitalists, Asymmetric Information and Ownership in the Innovation Process*

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Abstract

This paper provides a theoretical explanation of the role of venture capitalists in the innovation process. We add to this literature by showing that an aggressive development into innovative ideas by better informed venture-backed firms is used as a signaling device to enhance the sale price of the innovation. In turn, the emergence of a venture capital market can increase the sale price of basic ideas, since incumbents can be willing to conduct preemptive acquisitions to prevent such signaling driven overinvestment. We then show that when ideas are very good and there are high relative returns to development, aggressive development takes place which increases the sales price of the innovation more than the profit associated with IPOs.

Keywords: venture-backed firm, innovation, signaling, overinvestment, interim development, M&A, IPO

JEL codes: C7, D21, D82, L2

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1 Introduction

Venture-backed firms have been shown to be very aggressive in their early stage development of innovations. Increased venture capital activity is associated with relatively higher patenting rates, as shown by Kortum and Lerner (2000), with a significant reduction in the time required for bringing a product to the market, as in Hellmann and Puri (2000), and with higher levels of investments in R&D, as shown in Okamuro and Zhang (2005).

In the literature, the ability to solve moral hazard problems and the exploitation of strategic product market effects have been suggested to explain why venture capitalists are more aggressive and more successful in creating commercialized innovations.\(^1\) We add to this literature by showing that an aggressive development into innovative ideas by better informed venture-backed firms is used as a signaling device to enhance the sale price of the innovation. In turn, the emergence of a venture capital market can increase the sale price of basic ideas, since incumbents may be willing to conduct preemptive acquisitions to prevent such signaling driven overinvestment.

To this end we construct a model with two key ingredients. First, it is assumed that venture capitalists are better than incumbents in judging whether or not an idea is good or bad. Indeed, venture capitalists seem to have an advantage over incumbents in the industry in selecting firms with high innovative potential as suggested by Engel and Keilbach (2005), as well as a capacity in selecting innovator firms over imitator firms, as shown by Hellmann and Puri (2000).\(^2\) Second, it is assumed that the exit of the venture-backed firm takes place by the acquisition of an incumbent firm.\(^3\) In fact, acquisitions are an increasingly important mode of exit for venture-backed firms. For instance, Cochrane (2005) shows that 20% of the ventures were acquired, 21% were Initial Public Offerings IPOs, 9% went out of business, while 49% remained private.

We then construct a model where a market is served by two 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 good idea or a bad idea. The idea requires additional development for commercial use. The entrepreneur cannot develop the idea herself and, in a second stage, she may sell it to one of the incumbent firms. Alternatively, the entrepreneur can seek support from a venture capitalists. We assume the venture-backed firm to be perfectly informed about the nature of the idea, while the duopolists

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\(^2\) This may be due to the fact that both the entrepreneur and the venture capitalist had previous experiences with multiple ideas and/or in multiple markets where ideas could be potentially developed. Alternatively, assume that there is imperfect protection of Intellectual Property Rights on the side of the entrepreneur. Then the incumbents’ ability to develop the innovation on their own and the venture capitalist’s inability to do so may result in asymmetric incentives to fully disclose the characteristics of the innovation to these parties on the side of the entrepreneur simply because he fears expropriation by the incumbents but not by the venture capitalist.

\(^3\) Other studies show that venture firms acquire innovative targets in order to gain access to their technologies, see Granstrand and Sjölander (1990) or Hall (1990), for know-how transfers, see Lerner and Merges (1998) for US high-tech industries, or to substitute for in-house R&D activities, see Bloningen and Taylor (2000) for the biotech industry.
initially only have *prior beliefs* about an idea to be *good* or *bad*. We model the sale of the idea as a first price sealed bid auction, where incumbent firms and venture capitalists bid for the idea. If the entrepreneur "sells" the idea 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. Moreover, the size of this investment serves a signal, where it is assumed that it is more costly to invest when the idea is bad than when it is good. The venture-backed firm will then exit by selling the *developed* idea 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 first show that the better informed venture-backed firms use "overinvestment" to signal a good quality of the innovation to be sold to the incumbents, i.e. there exists equilibrium where the venture-backed firm’s investment is higher than the acquiring firms preferred investment level.

We then turn to the issue of whether the incumbent firms benefit from waiting and letting the venture capitalist sort between good and bad ideas. Indeed, we show that there exists equilibrium where the incumbents wait, and let the more informed venture capitalist screen the projects before acquiring. However, we also show that there exists an equilibrium where the incumbents do not wait, but use a preemptive acquisition. That the incumbent acquires the uncertain idea and does not let the venture capitalist screen the project and undertake a productive signal seems counter intuitive at first sight, in particular since the venture capitalist has to pay for the productive signal. However, this behavior may be understood taking into account how the signal affects the *acquisition price* of the developed innovation in this oligopolistic setting. In equilibrium, the acquisition price of the developed innovation is shown to equal an incumbent firm’s valuation of obtaining the developed innovation which, in turn, consists of the acquiring firm’s profit net its profit, if the developed innovation is obtained by a rival firm. The signal through increased investments increase the acquisition price more than it increases the acquirers profit, since the acquisition price increases not from the 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).

In fact, the desire to preempt signaling-driven overinvestment by undertaking preemptive acquisitions implies that the emergence of a venture capital market can increase the reward for developing basic ideas. The reason is that the acquisition price of ideas then increases, since the credible threat of over investment by venture capitalist increases due to the signaling effect, and the cost of signaling is not paid in equilibrium. Consequently, the acquisition price of ideas increases and thereby the reward for developing ideas.

We then extend the analysis to allow the venture capitalist also to exit by means of an initial public offering (IPO) after investment in development are undertaken. We then show that venture-backed firms
exit through a sale to an incumbent when the innovation they are developing is good and when it has a high relative return to development. The reason is that good ideas and high relative return to development lead to more aggressive development which increases the sales price of the innovation more than the profit associated with IPOs. The reason is again that increased investments increases 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). Drastic innovations are therefore associated with ideas, which first are targets of venture capitalists, then subject to interim development and then sold to incumbents. Less innovative ideas if developed within a venture-backed firm, are instead exited through IPOs.

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 and where the venture capitalist is better informed about the status of entrepreneurs ideas. More in general, this paper might be seen as a contribution how different institutional settings, such as the presence of a venture capital market, affect the incentives for entrepreneurial innovations, which has been considered as a lack in the literature on entrepreneurship. In this vein it can also be seen as a contribution to the literature on industrial structure and innovation. We extend this literature by allowing for the interaction between entrepreneurs, venture capitalists and oligopolist in an environment with adverse selection problems; 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 signaling literature. Contrary to the standard Spence’s model, the signaling here even though still costly, is productive as well. Any unit of investment into the development of a good idea translates into an enhanced process/product. We have shown that in order to separate types, i.e. to signal whether the idea is good or bad, the venture-backed firm sometimes needs to make an investment into its interim development which is further exacerbated as compared to the overinvestment which would have been already observed in the absence of asymmetric information. Depending on the parameters of the model, the venture-backed firm, by separating types, creates on the one

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4 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.

5 For overviews see Audreatch and Achs () and Bianchi and Henrekson() Baumol (2004) stress the importance of the different roles played by small entrepreneurial firms and large established firms in the innovation process in the USA, where small entrepreneurial firms create a large share of break through innovations and where large establish firms provide more routinized R&D.

6 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.
hand the threat for duopolists of having to compete against an acquirer of an overdeveloped idea in stage 3, which triggers preemptive acquisitions behavior in stage 1, and on the other hand an opportunity to sort types, i.e. not having to acquire the idea today, risking to invest on it not optimally, but instead waiting until tomorrow when the nature of the idea will be revealed.

A crucial feature of the models in the signaling literature\textsuperscript{7} \textsuperscript{8}, which we share, is that a seller of a good use some device to signal the quality of the good. We add to this literature by focusing on a productive signal, i.e. a signal that affect the productivity of the asset (good) sold post signaling in ensuing product market interaction\textsuperscript{9}. Moreover, we add to the literature by endogenously determining the ownership of the innovation – before and after the possibility of a signal by the venture sender (venture capitalist). By this, we can determine how the emergence of a venture capital market affects the total output of commercialized innovations in the economy. We show that in order to exist in equilibrium, an independent seller (venture backed firm) must be sufficiently more efficient than incumbent firms when screening and developing the innovation; otherwise incumbents will block the investment by an early preemptive acquisition of the basic innovation.

The paper is organized as follows. Section 2 introduces the model. In section 3 we solve for a separating equilibrium, in which the venture-backed firm signals the nature of an idea, which is either good or bad. We then characterize under which conditions preemptive acquisitions or venture backing occur and which is the preferred mode of exit of a venture-backed firm.

2 The Model Setup

2.1 Main Ingredients

We consider a market with linear demand $Q(P) = a - bP$, where $a$ and $b$ are positive parameters and $P$ is the price of the product, where duopolists with symmetric unit production cost, $c$, compete à la Cournot. Let there be an entrepreneur with an idea\textsuperscript{10}, which, after having been developed, may lead to a reduction of the unit production cost - or, alternatively, may lead to an increase in the quality of the product, which consumers value and are ready to pay for. We consider two types of ideas, good ones and bad ones. For a

\textsuperscript{7} See, for instance, Reily (2001) for an overview.

\textsuperscript{8} This paper could also be seen as a contribution to the literature on auctions with externalities. See, for instance, Jehiel, Moldovanu and Stacchetti (1996) and Jehiel and Moldovanu (1996, 2000).

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 (1982) 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.

\textsuperscript{9} An exemption is Ben Shahar (2002) which allow for productive signaling in a real estate setting. However, no product effects are present, which are crucial to our results.

\textsuperscript{10} Ideas here stand for any invention or innovation an entrepreneur might come up with, which can be sold.
A good idea, a costly investment of size $x \geq 0$ in its development leads to a unit production cost reduction of $\Delta = x$, whereas for a bad one, any investment leads to $\Delta = 0$. Good and bad ideas are also associated respectively with less or more resource demanding development technologies.\footnote{We will describe more in detail the specific development cost function we adopt in our model in the rest of this section.}

Assume that, on his own, the entrepreneur does not have the means to undertake the development of his idea. He can either team up with a venture capitalist, forming a venture-backed firm, or sell the undeveloped idea to one of the duopolists in the market. We model this decision by the entrepreneur on whether to sell the idea to one of the duopolists or to team up with the venture capitalist, as a first price sealed bid auction: the two ex-ante symmetric duopolists and one venture capitalist are the bidders who compete for appropriating the idea to be developed for the market.

We assume that whether the idea is good or bad is not verifiable by a court at any point in time and, therefore, it is not contractible, but any investment made into the development of it is instead costlessly verifiable. We allow the venture-backed firm to be perfectly informed about the nature of the idea, while the duopolists initially only have prior beliefs about an idea to be good or bad. Duopolists assign a probability $\lambda \in [0, 1]$ to the event that the idea is good, and $1 - \lambda$ to the event that the idea is bad. Furthermore, we assume that both the entrepreneur and the venture capitalist share the same information about the duopolists’ priors. We finally assume that the nature of the idea is revealed to the market prior to the fixing of the optimal quantities of the product to be sold, however, absent any prior revelation mechanisms, the rest of the market will not acquire this information before that moment.

We can think that priors reflect the proportion of how often an idea an entrepreneur comes up with turns out to be good, in a given market. The industry shares the same prior, so both duopolists are equally optimistic or pessimistic about the probability of facing a given type of idea when offered to them for sale. Once an idea is acquired by a competitor on the market, its nature will be revealed, but only at the end of its development, i.e. only after a given production process will have been tested and found out to be good, or bad, or only after a given product enhancement will have been achieved, or not. Additional investments into the development of good ideas, after that moment, are ruled out.

The informational assumptions made above when taken together imply that, absent any other information revelation mechanisms at play, the nature of the idea would not yet be known at the moment an investment decision has to be taken by an acquirer, while the venture-backed firm knows it when deciding upon its development. This makes the timing of the game an interesting one and creates the scope for analyzing the possibility of observing a signaling game between the venture-backed firm, if formed, and the rest of the market.

The investment decision will be made according to the information each of the players in this game will have. If one of the duopolist gets the idea in the initial auction, the idea will be developed according to its
associated expected return in the final competition stage, which in turn depends on the duopolists’ prior beliefs about the idea being good or bad. If instead the entrepreneur decides to team up with the venture capitalist, the venture-backed firm may invest in an \textit{interim development} of the idea, prior to selling it on the market, either to one of the duopolists in a M\&A, or in an IPO, which would then correspond in our model to the entry of a further player in this market (i.e. it would lead to a \textit{triopoly} in the final competition stage). We assume that the level of the interim investment into the development of the idea by the venture-backed firm, as well as any investment made into the development of the idea by any other acquirer, is costlessly \textit{verifiable} by both the duopolists and the potential buyers in an IPO, and \textit{irreversible}, no matter whether it has been made by the venture-backed firm or any other acquirer. Finally, we allow an acquirer of a partially developed idea, i.e. either a duopolist having acquired it in a M\&A, or an entrant in an IPO, to be able to invest on it further, but, given the irreversibility of the investment, not to be able to recoup the investment costs already incurred by the venture-backed firm instead.

The overall development costs of an idea, $C(x)$, are defined as follows:

$$C(x) = \frac{\mu (x_V + x_A)^2}{2},$$

with $x = x_V + x_A$, where $x_V$ stands for the investment by a ‘venture-backed’ firm, and $x_A$ stands for the investment by an ‘acquirer’, and where

$$\mu = \begin{cases} 
\mu_g & \text{if idea is ‘good’} \\
\mu_b & \text{if idea is ‘bad’} 
\end{cases}$$

with $0 < \mu_g < \mu_b < \infty$, i.e. one unit of investment made into good ideas is less costly than one unit of investment made into bad ideas. As already anticipated, an idea is not only either bad or good in its capacity of delivering a successful development at the end of a given period, but it is also bad or good in the sense of being more or less resource consuming during this development process.

Notice that if the idea is developed by the venture-backed firm, this firm will incur only the following partial costs:

$$C(x_V) = \frac{\mu x_V^2}{2},$$

while if the idea is developed by an acquirer, other than the venture-backed firm, this acquirer will have to incur the following costs instead:

$$C(x_A) = \frac{\mu (x_V + x_A)^2}{2} - \frac{\mu x_V^2}{2}.$$

Depending on whether the idea has been acquired initially or after an interim development by the venture-backed firm, the acquirer will have to incur all the development costs itself, or only the ones additional to the costs already incurred by the venture-backed firm. If $x_V = 0$, i.e. no interim development by the venture-backed firm has been made, the development costs for an acquirer are simply $C(x_A) = \frac{\mu x_A^2}{2}$. If an
acquirer decides not to invest into the development of an idea, i.e. if \( x_A = 0 \), he will not have to bear any cost: \( C(x_A) = 0 \).

### 2.2 Timing

Let us summarize the timing of the game in the extensive form described in figure 1.

#### Figure 1: Timing

In **stage 0**, an entrepreneur, \( E \), has an idea which has either a good or a bad potential for development.

In **stage 1**, the entrepreneur sells his idea in a first price sealed bid auction to one of the following players: two duopolists and one venture capitalist. Venture capitalist are perfectly informed about the idea being good or bad; while the duopolists have priors beliefs about the idea being good, or bad: they assign probability \( \lambda \) to the idea being good and probability \( 1 - \lambda \) to the idea being bad.

If one of the duopolists wins the auction, we move directly to **stage 4**. If the venture capitalist wins instead a venture-backed firm is formed and the game goes to **stage 2**.

In **stage 2**, the venture-backed firm invests \( x_V \) into an interim development of the idea.

In **stage 3**, the venture-backed firm first decides whether to sell the partially developed idea in a M&A to one of the duopolists or in an IPO, thereby inducing the entry in the market of a third player.
In stage 4: (i) if the idea was sold by the venture-backed firm in stage 3, the acquirer (A) can increase the level of the interim development by $x_A$ and the final investment into the idea corresponds to $x = x_V + x_A$; (ii) if the invention was sold to a duopolist by the entrepreneur already in stage 1, the acquirer (A) invests directly $x = x_A$.

In stage 5, the acquirer (A) and the non-acquirer(s) (NA) compete à la Cournot, setting quantities $q_A$ and $q_{NA}$, respectively.

In the next section we will develop our analysis solving this game by backward induction, and we will characterize the conditions for a separating equilibrium to exist. The separating equilibrium we will look for is one in which the venture-backed firm has an incentive to reveal the nature of the idea, prior to selling it afterwards to the market. For that we will need to explore whether the venture-backed firm can use the interim development as a signaling device for the nature of the idea to the market, i.e. to choose the appropriate level of investment into the idea which is able to separate good ideas from bad ones.

3 Analysis

In this section we solve the game described in section 2 by backward induction, searching for a perfect Bayesian (separating) equilibrium, in which, if a venture backed firm has been formed, it perfectly signals the idea’s nature to the possible acquirers. Notice that for this, we will need to distinguish in which part of the tree competition is played, either in a duopolistic or a triopolistic environment. We will have a duopoly in the product market, either whenever a duopolist has acquired the idea in stage 1 directly from the entrepreneur, and then competes on the product market against the non-acquirer firm; or because in stage 3 a duopolist gets the partially developed idea from a venture-backed firm through a M&A, and then competes with the non-acquirer firm in a similar way. However, we will have a triopoly situation, whenever in stage 3 the venture-backed firm sells the partially developed idea through an IPO. In this case, the newly established firm enters the competition with the other two non-acquirer firms which were already present in the market.

To solve for a separating equilibrium, in addition to having to distinguish whether we are in a duopolistic or a triopolistic competition case, we will also need to subdivide our analysis depending on whether the idea is good or bad to start with.

\[\text{12 Remember that at the moment competition is played on the market, the nature of the idea is publicly revealed and depending on whether in stage 3 the venture-backed firm decides to sell the partially developed idea through a M&A or an IPO, in stage 5 firms on the market will compete in a duopoly or a triopoly respectively.}\]
3.1 Stage 5: Cournot Competition

3.1.1 Optimal Quantities if Duopoly \((D)\)

We now focus our analysis on the subcases where in the final competition stage firms are in a duopoly. Therefore, we concentrate on either the left hand side of the tree as described in the extensive form game, or the left hand side of the right hand side of this tree. Remember that in stage 5 the information about the nature of the idea is revealed to all the players in the game when setting quantities and competing on the market, regardless of the existence of a separating equilibrium or not. At this stage the nature of the idea is revealed to the market.

**Idea is good \((g)\)** Let us start from the decision firms take over quantities, when the idea is good and when firms are competing in a duopoly:

\[
q_{A}^{D,g}(x) = \frac{a-c+2x}{3b}, \quad (1) \\
q_{NA}^{D,g}(x) = \frac{a-c-x}{3b}. \quad (2)
\]

These are the optimal quantities when two firms compete, but one of them has a cost advantage over the other\(^\text{13}\).

These quantities would lead to the following product market profits, respectively for the acquirer and the non-acquirer firm:

\[
\pi_{A}^{D,g}(x) = b \left( \frac{a-c+2x}{3b} \right)^2, \quad (3) \\
\pi_{NA}^{D,g}(x) = b \left( \frac{a-c-x}{3b} \right)^2. \quad (4)
\]

**Idea is bad \((b)\)** When the idea is bad, firms keep on competing in a symmetric way, and set the levels of their optimal quantities as in the absence of the idea:

\[
q_{A}^{D,b} = q_{NA}^{D,b} = \frac{a-c}{3b}. \quad (5)
\]

The associated product market profits are:

\[
\pi_{A}^{D,b} = \pi_{NA}^{D,b} = b \left( \frac{a-c}{3b} \right)^2. \quad (6)
\]

\(^{13}\)Remember that we could reinterpret this advantage in terms of the superior quality of the product to be sold on the market instead by one firm, but not the other.
3.1.2 Optimal Quantities if Triopoly (T)

Let us move our attention to the right hand side of the right hand side of the extensive form tree as depicted in figure 1. After an IPO has facilitated\textsuperscript{14} the entry of an additional player into the final competition stage of the game, we observe a triopoly in which one new firm may have a comparative advantage over the ones previously present in the market.

**Idea is good (g)** If the idea is good and if firms are competing in a triopoly, optimal quantities are set in the following way, respectively by the new firm who acquires the venture-backed firm through an IPO, and the other firms already established in the market:

\[
q_{T,g}^A(x) = \frac{a - c + 3x}{4b}, \quad q_{T,g}^{NA}(x) = \frac{a - c - x}{4b}.
\]

These quantities will lead to the following product market profits:

\[
\pi_{T,g}^A(x) = b \left( \frac{a - c + 3x}{4b} \right)^2, \quad \pi_{T,g}^{NA}(x) = b \left( \frac{a - c - x}{4b} \right)^2.
\]

**Idea is bad (b)** If the idea is bad, firms can only compete in a symmetric way, so that the optimal quantities are simply:

\[
q_{T,b}^A = q_{T,b}^{NA} = \frac{a - c}{4b}.
\]

The associated product market profits are:

\[
\pi_{T,b}^A = \pi_{T,b}^{NA} = b \left( \frac{a - c}{4b} \right)^2.
\]

3.2 Stage 4: Development

We are now moving backward up to stage 4, where the development of an idea needs to be decided upon by an acquirer, either a duopolist who acquired the idea directly in stage 1, a duopolist who acquired it in stage 3 through a M&A, or an entrant who got it through an IPO in stage 3. In these cases, whenever the idea has been acquired in stage 3, we will focus on the existence of a separating equilibrium when solving our model.

\textsuperscript{14}IPOs might be solving for some lack of coordination among dispersed potential shareholders.
Definition 1 A separating equilibrium is characterized by a level of investment into the interim development of an idea by a venture-backed firm which signals the nature of this idea to each potential acquirer in the market.

3.2.1 Subcase 1: Duopolist acquired the undeveloped idea in stage 1

Suppose we are in the left hand side of the tree as described in the extensive form game. In this case, the duopolist needs to decide upon the level of the investment to be made into the idea, $x_A$, prior to getting to know its nature. The duopolist can only set the investment level according to his prior beliefs.

The duopolist who acquired the idea in stage 1 therefore solves for the following problem:

$$\max_{x_A} \left[ \lambda \left( \pi_A^{D,g} (x) - \frac{\mu_g x_A^2}{2} \right) + (1 - \lambda) \left( \pi_A^{D,b} (x) - \frac{\mu_b x_A^2}{2} \right) \right],$$

i.e. he maximizes the expected gross profits of commercializing an idea on the market after having undertaken a costly investment into it. Note that in stage 4, when deciding upon the investment level, the acquirer needs to reason in expectations also with respect to the overall investment costs, given the nature of the idea is not yet known at that moment and that its nature determines as well how resource demanding an investment into its development will be.

The solution to this problem gives the optimal investment level the duopolist would choose in this situation, which is going to be a function of his prior beliefs about whether the idea is indeed good or bad:

$$x^\lambda = \frac{4 \lambda (a - c)}{9 ((1 - \lambda) b \mu_b + \lambda b \mu_g) - 8 \lambda}$$

The profit maximizing investment $x^\lambda$ equals the overall investment made into the development of an idea in this particular case.

This optimal investment level would lead to the following expected gross return:

$$E\Pi_D (x^\lambda) = \lambda \left( \pi_A^{D,g} (x^\lambda) - \frac{\mu_g (x^\lambda)^2}{2} \right) + (1 - \lambda) \left( \pi_A^{D,b} (x^\lambda) - \frac{\mu_b (x^\lambda)^2}{2} \right)$$

$$= (a - c)^2 \frac{1}{9} \frac{(1 - \lambda) (8 \lambda - 9 b \mu_b - 9 \lambda b \mu_g)}{\lambda (8 + 9 b \mu_b - 9 b \mu_g) - 9 b \mu_b - 9 \lambda b \mu_g}$$

Notice that if the duopolist acquiring the idea had perfect information about the idea being good, i.e. if $\lambda = 1$, then his optimal investment level into the development of this good idea, and its associated product

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15Gross of the bid that has been paid in order to get the idea to be developed at first.
16Therefore we have labelled this investment as $x^\lambda$ to distinguish it from the any other investment decision taken by an acquirer who gets the idea after it has been partially developed by a venture-backed firm instead.
17Remember that we assumed that the investment decisions are irreversible. This leads to having to take once for all decision over the level of the investment to be put into the development of an idea, before being able to see the result of the investment itself. Each player of the game we describe can only take this decision once. If the idea is acquired from a venture-backed firm having invested into the development of the idea, the acquirer still has the power to decide how much to invest further into it.
18Either because all the ideas in an industry are good by default, or if he could simply have access to the tacit information the entrepreneurs has about the idea being indeed a good one, for example.
market profits, would have been:

\[ x^\lambda = \frac{4(a-c)}{9b\mu_g - 8}, \]  \hspace{1cm} (16)

\[ \pi_A (x^\lambda) - \frac{\mu_g (x^\lambda)^2}{2} = \frac{\mu_g (a-c)^2}{9b\mu_g - 8}. \]  \hspace{1cm} (17)

Instead, had the duopolists shared the prior that the idea offered on the market is a bad one, i.e. if \( \lambda = 0 \), no investment into its development would have been made at all. So that:

\[ x^\lambda = 0, \]  \hspace{1cm} (18)

\[ \pi_A (x^\lambda) - \frac{\mu_b (x^\lambda)^2}{2} = \frac{b (a-c)}{3b}. \]  \hspace{1cm} (19)

3.2.2 Subcase 2: Duopolist acquired the partially developed idea in stage 3 from the venture-backed firm through a M\&A

Suppose now to be in the left hand side of the right hand side of the tree as described above. In this case, the idea has been sold through a M\&A to a duopolist who needs to decide whether, and in case how much, to invest into the idea which has been already partially developed by the venture-backed firm.

We would like to remind the reader that in this case we are solving for a possible separating equilibrium of the game, following definition 1. In a separating equilibrium, in stage 4 an acquirer of an idea through a M\&A knows its nature when deciding whether to develop it any further: on the one hand, knowing that any development of a bad idea leads to \( \Delta = 0 \) it will not be worth to invest anything into it; on the other hand, knowing instead that a good idea has been acquired would require an optimal choice of the investment to be put into the development of an idea. The acquirer duopolist of a good idea solves for:

\[
\max_{x_A} \left[ \pi_A (x_A + x_V) - \left( \frac{\mu_g (x_V + x_A)^2}{2} - \frac{\mu_g x_V^2}{2}\right) \right].
\]  \hspace{1cm} (19)

This implies that the optimal investment by an acquirer of a good idea in stage 3 through a M\&A, \( x_A^{D,g} (x_V) \), would be such that:

\[
x_A^{D,g} (x_V) = \begin{cases} 
\frac{4(a-c)}{9b\mu_g - 8} - x_V & \text{if } x_V < \frac{4(a-c)}{9b\mu_g - 8}, \\
0 & \text{otherwise}.
\end{cases}
\]  \hspace{1cm} (20)

The acquirer duopolist would like to invest more into the development of the idea, only as long as the interim development by the venture-backed firm is lower than the optimal unconstrained one he would have chosen had he acquired the idea in stage 1 and already known its nature when being in stage 4. In any other case, if the venture-backed firm’s investment would be larger than this unconstrained optimal level, the acquirer duopolist would prefer not to invest any further into the development of the acquired idea.

The associated total investment is:

\[ x^{D,g} = x_A^{D,g} (x_V) + x_V. \]  \hspace{1cm} (21)

3.2.3 Subcase 3: Idea was sold in stage 3 through an IPO

Let us continuing solving for a separating equilibrium, in which the venture-backed firm signals the nature of the idea. As above, the acquirer of a bad idea will not invest anything into its development. If the idea, which was sold through an IPO in stage 3, is a good one instead, the entrant (acquirer triopolist) will solve the following problem when deciding upon its optimal investment level:

$$\max_{x_A} \left[ \pi_A^{T,g}(x_A + x_V) - \left( \frac{\mu_g (x_V + x_A)^2}{2} - \frac{\mu_g x_V^2}{2} \right) \right].$$

(22)

Therefore, the optimal investment level for an acquirer triopolist when the idea is good, $x_A^{T,g}(x_V)$, is:

$$x_A^{T,g}(x_V) = \begin{cases} \frac{3(a-c)}{8b\mu_g - 9} - x_V & \text{if } x_V < \frac{3(a-c)}{8b\mu_g - 9}, \\ 0 & \text{otherwise}. \end{cases}$$

(23)

The total investment in this case is:

$$x^{T,g} = x_A^{T,g}(x_V) + x_V$$

(24)

Note that even when an idea is bad an IPO could lead to the sale of the venture-backed firm to potential buyers. In this case, the idea would not be developed any further, but acquiring a venture-backed firm with a bad idea could still be appealing for buyers as it still allows them to enter a market where they would not be present otherwise. In our model, the IPO exit mode is therefore always associated with a triopoly, with one acquirer (of a good or a bad idea) and two non-acquirers competing à la Cournot in the product market.

3.3 Stage 3: M&I or IPO

Proceeding backwards, we will have to determine under which conditions a venture-backed firm prefers to exit the market through a M&I or an IPO, after having invested into an interim development of the idea. As above, we do so assuming a separating equilibrium exists, according to definition 1. In this case, the venture-backed firm will prefer one or the other mode of exit depending on their respective sale prices it is able to induce on the market. These prices will ultimately depend on the valuations of the potential buyers: duopolists for a M&I and an entrant in an IPO. We are now moving in the right hand side of the tree as described in figure 1.

3.3.1 If M&I

Let us imagine that the venture-backed firm proposes itself for sale after the interim development occurred. A sale price is fixed according to the willingness to pay of the two symmetric duopolists in the market. We could model this sale as a take-it-or-leave-it offer, made to either of the duopolists, or as a first price sealed
bid auction which would convey the duopolists as bidders in order to acquire the partially developed idea by the venture-backed firm.

If the idea is good, the venture-backed firm can make an offer as follows:

$$S^D,g_3 = \pi^D,g_A (x^D,g) - \left( \frac{\mu_g (x^D,g (x_V) + x_V)^2}{2} - \frac{\mu_g x_V^2}{2} \right) - \pi^D,g_{NA} (x^D,g)$$  \hspace{1cm} (25)

where $S^D,g_3$ is the sale price of a venture-backed firm in stage 3 after the interim development of a good idea has been made. The sale price is given by the difference between the product market profits of being an acquirer of a good idea in a duopoly, the eventual additional investment to be made into the development of the already partially developed idea, and the product market profits associated with being a non-acquirer in a market and having to compete against a very aggressive competitor which acquired a good idea.

It is in the interest of the venture-backed firm to make this difference as high as possible. The optimal investment level chosen by the venture-backed firm will be affected by this incentive, as well as by the potential need to incur a costly signaling in order to reveal the nature of the idea to be then resold on the market. We will get into more details about the signaling behavior when solving for the decision to be taken in stage 2 by the venture-backed firm.

If the idea is bad, the duopolists cannot gain anything from acquiring the idea and the venture-backed firm could at most demand a payment of zero for them to acquire it.

### 3.3.2 If IPO

Let us now consider the possibility for the venture-backed firm to go public through an IPO. Remember that in an IPO many potential buyers, who would otherwise be dispersed in the market, can get together and acquire the venture-backed firm becoming shareholders. Going public corresponds to raising funds from these buyers by issuing equities on the venture-backed firm. Thus, only the structure of the ownership will be affected by the IPO, but not the way competition will be played on the market afterwards. In a separating equilibrium the level of funds to be raised at all will depend only on whether the idea was good or bad. The entrant will have an advantage in being an aggressive competitor in a triopoly when the idea was good, or will compete in the market in a symmetric way with the already established firms when the idea was bad. An IPO can therefore raise funds up to the level of the gains of running the business and commercializing the product in the market, net of an eventual investment into an additional development of the already partially developed idea.

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19 Going to one of the duopolists with such an offer, would lead to the duopolist accepting it, as long as the sale price was fixed according to the maximum willingness to pay of this duopolist. The alternative would be to refuse it, thereby facing the undesired outside option of being a non-acquirer in the market against a very aggressive competitor.
If the partially developed idea is good, then the funds which can be raised are given by:

$$S_{T,g}^3 = \pi_{T,g}^A (x_{T,g}^A (x_{V}^A + x_{V})^2 - \mu_g x_{V}^2),$$

(26)

where $S_{T,g}^3$ is the overall sale price of the equities for the venture-backed firm to go public in this case. It corresponds to the triopoly product market profit of an acquirer of a good idea net of the eventual additional costs of development.

If the partially developed idea is bad, then the funds which can be raised correspond to the profit of a firm competing à la Cournot in a symmetric triopoly, i.e.:

$$S_{T,b}^3 = \pi_{T,b}^A,$$

(27)

where $S_{T,b}^3$ is the overall sale price of the equities for the venture-backed firm to go public in this case. Notice that in this case the outside option of not being in the market, as well as the additional investment to be made, amount to zero.

### 3.4 Stage 2: Interim Development - Signaling

In stage 2, the venture-backed firm decides upon the interim development of the idea, prior to reselling it to the market, either in a M&A or in an IPO. Remember from stage 3 that, in a separating equilibrium, with a bad idea, the venture-backed firm is able to raise funds by going public, but it cannot sell the idea through a M&A. We can summarize this by saying that if an idea is bad and the entrepreneur teams up with the venture capitalist forming a venture-backed firm, they do not invest anything into its development and resell it on the market through an IPO which is valuable to potential buyers as it allows for their entry into a market where they could not enter otherwise.

From now on let us concentrate then on the more interesting case of the development of a good idea by the venture-backed firm. Let us remember that we are focussing our attention on the existence of a separating equilibrium as described in definition 1.

Before doing so, let us anticipate that in our model the venture-backed firm’s investment into the signal (interim development) is value-enhancing. This is in contrast to the Spence’s (1973) Job Market Signaling model: In that model, investing into the signal is wasteful in terms of the productivity of the worker. As a result, the wage a good worker gets on the labor market will only depend on the ability to separate himself from bad ones, but not on the education level itself. In our model, investing into the interim development of the idea serves two purposes instead. It is a signal that separates good from bad ideas, and it endogenously determines the sales price in stage 3 as well. As a consequence, we will see that under given combinations of the parameter space of the model an unconstrained interim development into a good idea may be also sufficient for signaling purposes, i.e. that the incentive compatibility constraint for signaling to occur does
not necessarily always have to be binding. In the rest of this section, we will therefore first solve for the unconstrained investment level, then check whether it satisfies the incentive compatibility constraint which ensures that a separating equilibrium exists, and only if it does not, we will solve for the lowest necessary investment level which satisfies incentive compatibility.

### 3.4.1 If M&A

#### Unconstrained interim development

If a venture-backed firm could choose the level of the investment to be made into the interim development of the idea without having to internalize the constraint of having to signal its nature, the solution to its unconstrained maximization problem would lead to the *unconstrained interim development for a good idea prior to a M&A*, $x_{D,g}^V$, such that:

$$x_{D,g}^V = \max_{x_V} \left\{ S_{3,g} - \frac{\mu_g x_V^2}{2} \right\} = \frac{2(a - c)}{3b\mu_g - 2}.$$  

(28)

Note that:

$$x_{D,g}^V = \frac{2(a - c)}{3b\mu_g - 2} = \frac{2\eta_g (a - c)}{3 - 2\eta_g} > \frac{4\eta_g (a - c)}{9 - 8\eta_g} = \frac{4(a - c)}{9b\mu_g - 8} = x_{A,g}^A (0) \Leftrightarrow \eta_g < \frac{3}{4},$$  

(29)

where $\eta_g = \frac{1}{b\mu_g}$ can be interpreted as the relative return to development of a good idea (increasing in market size $\frac{1}{b}$ and decreasing in development costs $\mu_g$). Given that, as long as $\eta_g < \frac{3}{4}$, the innovation is non-drastic, this inequality implies that as long as the non-acquiring competitor would still produce a positive quantity in the final market, the interim development level exceeds the investment level a perfectly informed duopolist acquirer would have chosen himself.

This suggests that even if the venture-backed firm was unconstrained in its development decision by the need of having to signal the true nature of the idea, there would still be overinvestment. Overinvestment here implies that the acquirer duopolist of a good idea would decide not to invest any further into its development. In addition, given the investment is irreversible, there is no possibility for the acquirer to reduce it up to the level which would have been desired instead, in order to recover some of the development costs put into it by the venture-backed firm. The duopolist acquirer pays a price for getting the partially developed idea, which ultimately depends on the development investment costs incurred by the venture-backed firm, does not to invest any further into the idea, and then competes as an acquirer on the market.

The venture-backed firm, if it could choose the unconstrained development level, would then make the following net gains:

$$\Pi_{D,g}^V = \frac{2(a - c)^2}{b(9b\mu_g - 6)}.$$  

(30)

---

20A high $\eta_g$ corresponds, for a given marginal development cost, to a large market size, or, for a given market size, to low marginal development costs of a good idea.
However, this investment level induces a separating equilibrium if and only if it suffices to reveal the true nature of the idea as being good, i.e. if the following signaling incentive compatibility constraint for a good idea prior to a M&A is satisfied:

\[
S_3^{D,g} - \frac{\mu_b \left( x_{V}^{D,g} \right)^2}{2} < 0 \iff \eta_b < \frac{3\eta_g}{6 - 2\eta_g},
\]  

(31)

where \( \eta_b = \frac{1}{\theta b} \). The incentive compatibility constraint tells us that, what the venture-backed firm can get by selling a bad idea as if it was a good one, net of the associated costs of developing it, given it is a bad one, must be smaller than the outside option of revealing the true nature of the idea which equals to zero. The incentive not to mimic a good idea when bad associated with the level of the unconstrained interim development just found, is satisfied only as long as \( \eta_b < \frac{3\eta_g}{6 - 2\eta_g} \).

If the combinations of the parameters of the model are such that the inequality above is not verified the unconstrained interim development is not incentive compatible, so that the venture-backed firm will have to choose a higher level than \( x_{V}^{D,g} \) into the interim development of a good idea in order to signal that it is indeed a good one.

**Constrained interim development** If \( \eta_b \geq \frac{3\eta_g}{6 - 2\eta_g} \), the unconstrained optimal investment level \( x_{V}^{D,g} \) violates the incentive compatibility constraint (31). In this case, the venture-backed firm needs to invest a different amount, i.e. a level which is just sufficient to make the incentive compatibility constraint binding, in order to signal the nature of a good idea. Any additional investment above the unconstrained interim development level the venture-backed firm would have chosen, is a costly one. This extra costly investment only serves the purpose of signaling the real nature of the idea prior to resell it. It is in the interest of the venture-backed firm to invest though as little as possible above the level of the unconstrained interim development level which would have been optimally chosen otherwise, i.e. if the signaling constraint was not binding. The constrained interim development prior to a M&A, \( x_{V}^{D,s} \), will be determined by the level of investment which is just sufficient not to violate the signaling incentive compatibility constraint, i.e:

\[
x_{V}^{D,s} = \left\{ x_{V} \left| S_3^{D,g} - \frac{\mu_b \left( x_{V} \right)^2}{2} = 0 \right. \right\}
\]

\[= \frac{4(a - c)}{3b \mu_b - 2} \equiv 4\eta_b \frac{(a - c)}{3 - 2\eta_b},\]

(32)

where \( s \) stands for the ‘signaling’ constraint being binding. The level of this constrained interim development, \( x_{V}^{D,s} \), is higher than the level of the unconstrained interim development, which in turn implies that the need to signal that a good idea is indeed good, exacerbates the incentives for a venture-backed firm to overinvest into the development of the idea as compared to what duopolists in the market would have wanted to invest themselves, had they known the idea is a good one indeed.
Within a constrained signaling situation, the venture-backed firm when selling a good idea to a duopolist would obtain the following net gains:

$$\Pi_{V}^{D,s} = \frac{8(\mu_b - \mu_g)(a - c)^2}{(3b\mu_b - 2)^2}. \quad (33)$$

### 3.4.2 Intermediate results for signaling if M&A

These results extend the findings by Norbäck and Persson (2004). In their model no distinction between a good or a bad idea was made and no asymmetry of information between the duopolists and the venture-backed firm was allowed for. Having allowed for the existence of good and bad ideas and having assumed that there is an asymmetry of information between the duopolists and the venture-backed firm, lead to these intermediate findings which can be summarized in the following propositions:

**Proposition 1.** In a separating equilibrium, a venture-backed firm prior to a sale through a M&A:

(i) signals the bad nature of an idea by not investing anything into its interim development;

(ii) signals the good nature of an idea by choosing an unconstrained interim development, $x_{V}^{D,g}$, as long as $\eta_b < \frac{3\mu_g}{6 - 2\mu_g}$; and a constrained interim development, $x_{V}^{D,s}$, otherwise.

**Corollary 1.** In a separating equilibrium, a venture-backed firm prior to a sale of a good idea through a M&A overinvests into its interim development as compared to the optimal level an informed acquirer duopolist would have chosen to invest himself, similar to Norbäck and Persson (2004).

### 3.4.3 If IPO

Let us move to the subcase where the venture-backed firm may instead decide to go public through an IPO. We will repeat here the same logical exercise as in the previous subsection, i.e. we will first solve for the unconstrained interim development prior to an IPO, and then check under which level of the parameter space of the model its level is signaling incentive compatible.

**Unconstrained interim development** Remember that in an IPO a venture-backed firm would try to maximize the funds which can be raised by going public. Thus, the unconstrained level of the interim development into a good idea prior to an IPO, $x_{V}^{T,g}$, is determined by:

$$x_{V}^{T,g} = \arg \max_{x_{V}} \left\{ S_{3}^{T,g}(x_{V}) - \frac{\mu_g x_{V}^2}{2} \right\} = \frac{3(a - c)}{8b\mu_g - 9}. \quad (34)$$

Note that in this case the unconstrained interim development by the venture-backed firm coincides with the level of the overall investment into the development of a good idea which an informed entrant would have chosen himself. The venture-backed firm and the entrant have aligned interests, given that for the entrant...
the level of the outside option of being out of the market, does not depend on the size of the investment in the development of the idea.  

The venture-backed firm would get the following net gain from investing into the idea the level which corresponds to this unconstrained interim development:

$$\Pi_{V \cdot g} = \frac{\mu_g (a - c)^2}{2(8b\mu_g - 9)}$$  

(35)

The level just found for the interim development of the idea would indeed be chosen only as long as it would be informative for the general public about the idea being good. For that, we need to verify under which condition the incentive compatibility constraint associated with this case holds. The unconstrained interim development of a good idea prior to an IPO is chosen by the venture-backed firm, as long as:

$$S_{T,g}^{3} - \frac{\mu_b (x_{V,g})^2}{2} < S_{T,b}^{3} \Leftrightarrow \eta_b < \frac{8\eta_g}{16 - 9\eta_g}.$$  

(36)

However, if $\eta_b \geq \frac{8\eta_g}{16 - 9\eta_g}$ the venture-backed firm will have to invest a higher amount into the interim development of the idea to signal to the market that the idea is indeed a good one. This level would correspond to the minimum investment level which satisfies the signaling incentive compatibility constraint for a good idea prior to an IPO.

**Constrained interim development** If $\eta_b \geq \frac{8\eta_g}{16 - 9\eta_g}$, the venture-backed firm will invest:

$$x_{V,s}^{T,s} = \left\{ x_{V} \mid S_{T,g}^{3} - \frac{\mu_b (x_{V})^2}{2} = S_{T,b}^{3} \right\}$$  

$$= \frac{6(a - c)}{8b\mu_b - 9},$$  

where $s$ stands for 'signaling' constraint being binding as before.

Within a constrained signaling situation, the venture-backed firm when going public would obtain the following net gains:

$$\Pi_{V \cdot s} = \frac{(a - c)^2 (8b\mu_b + 9)^2 - 288b\mu_g}{16b (8b\mu_b - 9)^2}.$$  

(38)

21Both the venture-backed firm and the potential shareholders, who would acquire rights on the firm through an IPO, are interested in enhancing the profits which would accrue to the firm after the competition stage is played, net of the investment costs which have been incurred prior to the IPO. In stage 3, the outside option of not acquiring a good idea for an established firm is not equal to zero instead. This outside option is equivalent to the profits as a non acquirer having to compete against an acquirer.
3.4.4 Intermediate results for signaling if IPO

As before, we can summarize these intermediate results for the IPO alternative exit mode for a venture-backed firm in the following proposition:

**Proposition 2** In a separating equilibrium, a venture-backed firm prior to a sale through an IPO:

(i) signals the bad nature of an idea by not investing anything into its interim development;

(ii) signals the good nature of an idea by investing an amount \( x_{V}^{T, g} = x_{A}^{T, g} \) into its interim development, i.e. an amount equivalent to the optimal level an informed acquirer triopolist would have chosen to invest himself, as long as \( \eta_{b} < \frac{8\eta_{g}}{16-9\eta_{g}} \); and an amount \( x_{V}^{T, s} > x_{V}^{T, g} \) otherwise.

3.5 M&Es or IPO?

We are now in the position to determine under which circumstances a venture-backed firm, once formed, would have an incentive to go on the market for sale through a M&Es or to go public in an IPO while signaling the nature of the idea. Whether the venture-backed firm will exit the market through a M&Es or an IPO will depend on which alternative is more profitable, which is affected by whether and which of the incentive compatibility constraints described above is binding. This ultimately depends on the level of the parameters of the model we consider.

Note that, within the parameter space \( \{\eta_{b}, \eta_{g}\} \), the set of the combinations of the parameters for which an interim development for a M&Es is unconstrained, is a subset of the set of combinations of these parameters for which an interim development for an IPO is unconstrained as well, i.e.:

**Lemma 1** \( \left\{ \{\eta_{b}, \eta_{g}\} \mid \eta_{b} < \frac{3\eta_{g}}{6-2\eta_{g}} \right\} \supseteq \left\{ \{\eta_{b}, \eta_{g}\} \mid \eta_{b} < \frac{8\eta_{g}}{16-9\eta_{g}} \right\} \).

**Proof.** \( \forall\eta_{g}, \frac{3\eta_{g}}{6-2\eta_{g}} < \frac{8\eta_{g}}{16-9\eta_{g}} \). \( \blacksquare \)

Lemma 1 defines three regions. In region I \( \eta_{b} \geq \frac{8\eta_{g}}{16-9\eta_{g}} \), so that the incentive compatibility constraints for both M&Es and IPO are binding. In region II \( \frac{3\eta_{g}}{6-2\eta_{g}} \leq \eta_{b} < \frac{8\eta_{g}}{16-9\eta_{g}} \), thus only the incentive compatibility constraint for the M&Es is binding, and in region III, where \( \eta_{b} < \frac{3\eta_{g}}{6-2\eta_{g}} \), neither incentive compatibility constraint is binding.

Before making the relevant comparisons in order to determine which exit mode is more profitable for the venture-backed firm depending on which combination of the parameter space is the relevant one, let us remind the following. In a M&Es the venture-backed firm’s net gains are:

\[
\Pi_{V}^{D} = \begin{cases} 
\Pi_{V}^{D,g} = \frac{2(a-c)^2}{1(9\eta_{b} + 6)} & \text{if } \eta_{b} < \frac{3\eta_{g}}{6-2\eta_{g}} \\
\Pi_{V}^{D,s} = \frac{8(\mu_{n} - \mu_{s})(a-c)^2}{(3\mu_{b} - 2)^2} & \text{if } \eta_{b} \geq \frac{3\eta_{g}}{6-2\eta_{g}}
\end{cases}
\]

whereas in an IPO the venture-backed firm’s net gains are:

\[
\Pi_{V}^{T} = \begin{cases} 
\Pi_{V}^{T,g} = \frac{\mu_{n}(a-c)^2}{2(8\eta_{b} + 9)} & \text{if } \eta_{b} < \frac{8\eta_{g}}{16-9\eta_{g}} \\
\Pi_{V}^{T,s} = \frac{(a-c)^2}{16} \frac{(8\eta_{b} + 9)^2 - 288\eta_{g}}{(8\eta_{b} - 9)^2} & \text{if } \eta_{b} \geq \frac{8\eta_{g}}{16-9\eta_{g}}
\end{cases}
\]
For $\eta_b \geq \frac{8\eta_g}{16-9\eta_g}$, both incentive compatibility constraints for a M&A and for an IPO are binding. Thus, the venture-backed firm will sell the interim-developed idea in a M&A iff

$$\Pi_{V}^{D,s} > \Pi_{V}^{T,s}. \quad (41)$$

For $\frac{3\eta_g}{6-2\eta_g} \leq \eta_b < \frac{8\eta_g}{16-9\eta_g}$, the incentive compatibility constraint for an interim development with signaling (signaling constrained interim development) is binding for a M&A, but not for an IPO. In this case, a M&A will be the chosen exit mode iff

$$\Pi_{V}^{D,s} > \Pi_{V}^{T,g}. \quad (42)$$

Finally, for $\eta_b < \frac{3\eta_g}{6-2\eta_g}$, none of the incentive compatibility constraints for an interim development with signaling, neither for a M&A nor for an IPO, is binding. In such a case, a M&A is chosen iff

$$\Pi_{V}^{D,s} > \Pi_{V}^{T,g}. \quad (43)$$

These inequalities, which reduce to conditions on $\eta_g$ and $\eta_b$, can be summarized in a graph, defined in the parameter space $\{\eta_b, \eta_g\}$. Figure 2 depicts the regions as described above, and illustrates which exit mode is preferred over which one by the venture-backed firm.

Note that in figure 2 we restrict the parameters $\eta_b$ and $\eta_g$ to vary over the interval $[0, \frac{2}{3}]$. We do so in order to maintain the viability of a triopoly in the industry when the idea is a good one, i.e. to allow a non-acquirer triopolist to be able to compete against an acquirer triopolist of a good idea.

**Proposition 3** For a good idea, a venture-backed firm would choose a M&A over an IPO as an exit mode if both the relative return to development of the good idea, $\eta_g$, and the difference in the development costs of a good and a bad idea, reflected by $\eta_g - \eta_b$, are sufficiently high.

### 3.6 Stage 1: Auction of the idea

We now move to *stage 1*, where we need to determine whether the idea will be sold by the entrepreneur to one of the duopolists or whether he would prefer to team up with a venture capitalist in order to form a venture-backed firm which will be responsible of investing ad interim, eventually, into the development of the idea prior to its sale to the market.

We model the sale of an idea in *stage 1* as a first price sealed bid auction, in which the two duopolists and the venture capitalist participate. As long as the duopolists participating in the auction are symmetric, as it is the case in our model, they will compete with each other for appropriating the idea, and given that they know each other’s valuation, they will bid their expected maximum valuation. The venture capitalist knows the duopolists’ expected valuations, and he knows what the idea is worth. The venture capitalist
bids the minimum between his valuation and the duopolists valuation plus $c$. Thus, the bidder with the highest valuation wins the auction. In the rest of this section we will therefore concentrate on the level of the valuations each of the participants in the auction has in order to determine who is the winner of the auction depending on the different values of the parameters of the model under consideration.

### 3.6.1 Duopolists’ valuations

The duopolists’ net expected profits are:

$$E\Pi^D(x^\lambda) = \lambda \left( \pi^D_a(x^\lambda) - \frac{\mu_g(x^\lambda)^2}{2} \right) + (1 - \lambda) \left( \pi^D_b(x^\lambda) - \frac{\mu_b(x^\lambda)^2}{2} \right).$$  \hspace{1cm} (44)

However, depending on which is the possible scenario in stage 5, duopolists when having to decide upon their bids in stage 1 will face different outside options which may lead to different possible valuations for being an acquirer of an idea.

Thus, a duopolist’s valuation of being an acquirer in stage 1 when the undeveloped idea would otherwise

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22 In practice, the venture capitalists will offer the entrepreneur a share in the venture-backed firm’s returns, which depends on the nature of the idea to be developed first and sold then either through a M&A or an IPO.
be obtained by the other duopolist in stage 1, $v_{A1}^D(x^\lambda)$, corresponds to:

$$v_{A1}^D(x^\lambda) = E\Pi^D (x^\lambda) - \lambda \pi_{NA}^{D,b}(x^\lambda) - (1 - \lambda) \pi_{NA}^{D,b}(x^\lambda). \quad (45)$$

A duopolist’s valuation of being an acquirer in stage 1 when the idea would otherwise have been obtained by the venture-backed firm, which is unconstrained in its signaling, and then exits the market by selling the partially developed idea to the other duopolist in stage 3, $v_{A1}^{D3}(x^D_V)$, corresponds to:

$$v_{A1}^{D3}(x^D_V) = E\Pi^D (x^\lambda) - \lambda \pi_{NA}^{D,g}(x^D_V) - (1 - \lambda) \pi_{NA}^{D,g}. \quad (46)$$

A duopolist’s valuation of being an acquirer in stage 1 when the idea would otherwise have been obtained by the venture-backed firm, which is constrained in its signaling, and then exits the market by selling the partially developed idea to the other duopolist in stage 3, $v_{A1}^{D3}(x^D_s)$, corresponds to:

$$v_{A1}^{D3}(x^D_s) = E\Pi^D (x^\lambda) - \lambda \pi_{NA}^{D,g}(x^D_s) - (1 - \lambda) \pi_{NA}^{D,s}. \quad (47)$$

A duopolist’s valuation of being an acquirer in stage 1 when the idea would otherwise have been obtained by the venture-backed firm, which is un constrained in its signaling, and then exits the market by going public in stage 3, $v_{A1}^{T3}(x^T_V)$, corresponds to:

$$v_{A1}^{T3}(x^T_V) = E\Pi^D (x^\lambda) - \lambda \pi_{NA}^{T,g}(x^T_V) - (1 - \lambda) \pi_{NA}^{T,b}. \quad (48)$$

Finally, a duopolist’s valuation of being an acquirer in stage 1 when the idea would otherwise have been obtained by the venture-backed firm, which is constrained in its signaling, and then exits the market by going public in stage 3, $v_{A1}^{T3}(x^T_s)$, corresponds to:

$$v_{A1}^{T3}(x^T_s) = E\Pi^D (x^\lambda) - \lambda \pi_{NA}^{T,g}(x^T_s) - (1 - \lambda) \pi_{NA}^{T,b}. \quad (49)$$

### 3.6.2 Venture-backed firm’s valuation

In the following we will restate the net gains from developing and reselling an idea for the venture-backed firm, associated with each incentive compatibility constraint, whether binding or not. We will then rename these gains as the venture-backed firm’s valuations, i.e. the venture capitalist’s valuation for acquiring the idea in the auction in stage 1.

**Idea is bad** Let us recall that if the idea is a bad one, it can always be sold in an IPO, and the venture-backed firm does not invest anything in its interim development in order to preserve the non-mimicking (or signaling) incentive compatibility constraints for a good idea. Thus, the valuation of the venture-backed firm for a bad idea in stage 1, $v_{V1}^b$, corresponds to

$$v_{V1}^b = \pi_{NA}^{T,b} = b \left(\frac{a - c}{4b}\right)^2. \quad (50)$$

**Idea is good**
Idea is good For a good idea, a venture-backed firm knows it will invest incentive compatible levels of development. Thus, the relevant valuations, depending on the different net gains the venture-backed firm can make out of each possible outcome, as described in stage 2, are

\[ v_{V1}^{D,g} = \Pi_{V}^{D,g} = \frac{2(a-c)^2}{b(9\mu g - 6)}, \]  
\[ v_{V1}^{D,s} = \Pi_{V}^{D,s} = \frac{8(\mu_b - \mu_g)(a-c)^2}{(3b\mu_b - 2)^2}, \]  
\[ v_{V1}^{T,g} = \Pi_{V}^{T,g} = \frac{\mu g (a-c)^2}{2(8b\mu_g - 9)}, \]  
\[ v_{V1}^{T,s} = \Pi_{V}^{T,s} = \frac{(a-c)^2 (8b\mu_b + 9)^2 - 288b\mu g}{(8b\mu_b - 9)^2}. \]

3.6.3 When do we have preemptive acquisitions (PA)?

In order to answer this question, we need to make different comparisons depending on which is the relevant combination of the set of parameters of interest of the model. In the remaining part of this subsection we will decompose our analysis in order to account for all these potential comparisons.

Case 1: \( \eta_b \leq \frac{3a_g}{6-2\eta_g} \) Here, the unconstrained interim development levels are incentive compatible both for a M&A and an IPO. Therefore, we need to further decompose the analysis considering whether \( \Pi_{V}^{D,g} > \Pi_{V}^{T,g} \) holds or not.

If \( \Pi_{V}^{D,g} > \Pi_{V}^{T,g} \) holds, the venture-backed firm is better off by developing the idea ad interim according to the unconstrained development level associated with a subsequent M&A instead of the one associated with an IPO. Therefore, in this case we would observe a preemptive acquisition by a duopolist as long as

\[ v_{A1}^{P3} \left( x_{V1}^{D,g} \right) > v_{V1}^{D,g}. \]  

For \( \Pi_{V}^{D,g} \leq \Pi_{V}^{T,g} \), the venture-backed firm is better off by developing the idea ad interim according to the constrained development level associated with a subsequent IPO instead of the one associated with a M&A instead. In this case, we will observe preemptive acquisition by a duopolist as long as

\[ v_{A1}^{P3} \left( x_{V1}^{T,g} \right) > v_{V1}^{T,g}. \]  

Case 2: \( \frac{3a_g}{6-2\eta_g} < \eta_b \leq \frac{8a_g}{16-9\eta_g} \) Here, unconstrained interim development level is incentive compatible only for an IPO but not for an M&A. Therefore, we need to further decompose the analysis considering whether \( \Pi_{V}^{D,s} > \Pi_{V}^{T,g} \) holds or not.

If \( \Pi_{V}^{D,s} > \Pi_{V}^{T,g} \) holds, the venture-backed firm is better off by developing the idea ad interim according to the constrained development level associated with a subsequent M&A instead of the one associated with an
IPO. For this case, a preemptive acquisition by a duopolist will occur if the following is true:

\[ v_{A1}^{D3} \left( x_{V}^{D,s} \right) > v_{V1}^{D,s}. \]  \hspace{1cm} (57)

For \( \Pi_{V}^{D,s} \leq \Pi_{V}^{T,s} \), the venture-backed firm is better off by developing the idea ad interim according to the unconstrained development level associated with a subsequent IPO instead of the one associated with an M&EA. We would observe preemptive acquisitions any time

\[ v_{A1}^{T3} \left( x_{V}^{T,g} \right) > v_{V1}^{T,g}. \]  \hspace{1cm} (58)

**Case 3:** \( \frac{8\eta_{a}}{10-9\eta_{a}} < \eta_{b} \) Here, the unconstrained interim development levels are incentive compatible neither for a M&EA nor for an IPO. Therefore, in this case the analysis needs to account for whether \( \Pi_{V}^{D,s} > \Pi_{V}^{T,s} \) holds or not.

If \( \Pi_{V}^{D,s} > \Pi_{V}^{T,s} \), the venture-backed firm is better off by developing the idea ad interim according to the constrained development level associated with a subsequent M&EA instead of the one associated with an IPO. As before, this would lead to preemptive acquisitions any time the following holds:

\[ v_{A1}^{D3} \left( x_{V}^{D,s} \right) > v_{V1}^{D,s}. \]  \hspace{1cm} (59)

For \( \Pi_{V}^{D,s} \leq \Pi_{V}^{T,s} \), the venture-backed firm is better off by developing the idea ad interim according to the constrained development level associated with a subsequent IPO instead of the one associated with a M&EA. Therefore, preemptive acquisitions will be observed for this case as long as

\[ v_{A1}^{T3} \left( x_{V}^{T,s} \right) > v_{V1}^{T,s}. \]  \hspace{1cm} (60)

Figures 3-8 show which are the combinations of the parameters of interest of the model which lead to either preemptive acquisitions by duopolists in stage 1, or to M&EAs or to IPOs in stage 3, for several degrees of asymmetric information (\( \lambda = 0.6 \), \( \lambda = 0.7 \), \( \lambda = 0.8 \), and \( \lambda = 0.9 \), when the idea is indeed a good one, and \( \lambda = 0.8 \), and \( \lambda = 0.9 \) when the idea is a bad one, respectively).

If the idea is a good one and the duopolists have pessimistic beliefs about the idea being good, i.e. if \( \lambda \) is low enough, the tendency to acquire preemptively is not very high. If the idea is a bad one and duopolists are optimistic about the idea being good instead, they may manage to acquire it preemptively more often than otherwise, given that for the entrepreneur it would be relatively less attractive to form a venture-backed firm with the venture capitalist and resell it going public than otherwise. In general, the more optimistic the duopolists’ priors the more preemptive acquisitions would be observed, some of which may reveal to be good acquisitions, indeed, and some of which may be 'lemons' instead. The increased inability for the duopolists to perfectly judge whether an idea is good or bad to start with decreases the potential of acquiring it preemptively. The alternative is to wait until the venture-backed firm invests into an interim development
first, which corresponds to ending up in a situation where the idea is overdeveloped, prior to have a chance to acquire it later on in a M&A.

Venture-backed firms use the interim development of the idea as a signaling device. Contrary to the standard Spence’s model, the signaling here even though still costly, is productive as well. Any unit of investment into the development of a good idea translates into an enhanced process/product\(^{23}\). We have shown that in order to separate types, i.e. to signal whether the idea is good or bad, the venture-backed firm sometimes needs to make an investment into its interim development which is further exacerbated as compared to the overinvestment which would have been already observed in the absence of asymmetric information. Depending on the parameters of the model, the venture-backed firm, by separating types, creates on the one hand the threat for duopolists of having to compete against an acquirer of an overdeveloped idea in stage 3, which triggers preemptive acquisitions behavior in stage 1, and on the other hand an opportunity to sort types, i.e. not having to acquire the idea today, risking to invest on it not optimally, but instead waiting until tomorrow when the nature of the idea will be revealed.

The duopolists face, thus, a dilemma between waiting and not waiting. A preemptive acquisition (not waiting) is equivalent to facing the risk of not investing optimally into an idea today, given the asymmetry of information, either because the idea is indeed a good one and the investment is below the optimal one which would have been chosen otherwise, or because the idea is a bad one and the duopolist, had he known the real nature of the idea, would have preferred not to invest anything into it at all. Postponing (waiting) may involve the risk of not being the acquirer of the idea: being a non-acquirer of an idea which has been overdeveloped ad interim implies having to compete against an acquirer which is going to be a very aggressive competitor in the final market. Therefore, the exacerbated overinvestment into a good idea due to the signaling increases further the threat of not acquiring the idea at first given the duopolist may end up being a non-acquirer tomorrow, but it also reduces the risks of not investing optimally today. These two effects are the driving forces of the duopolists’ behavior in stage 1, i.e. when the preemptive acquisition may be an option for them, at least as long as the combinations of the parameter space of the model would allow them to overbid the offer which a venture capitalist could make to the entrepreneur. Depending on the relative magnitude of the costs of the investment associated with a good or a bad idea, and on the priors duopolists share we will observe either preemptive acquisitions, or the postponing of the option to buy an idea, even if this means it will be an overdeveloped one.

\(^{23}\text{Depending on the interpretation of the model, on whether an idea is good in increasing the quality of a product to be sold on a market, or in reducing its unit production costs instead.}\)
Figure 3: Equilibrium for a good idea when $\lambda = 0.6$

Figure 4: Equilibrium for a good idea when $\lambda = 0.7$
Figure 5: Equilibrium for a good idea when $\lambda = 0.8$

Figure 6: Equilibrium for a good idea when $\lambda = 0.9$
Figure 7: Equilibrium when idea is bad for $\lambda = 0.8$.

Figure 8: Equilibrium for a bad idea when $\lambda = 0.9$.
We can summarize results for the auction in stage 1 as follows:

**Proposition 4** For a good idea, preemptive acquisitions, instead of late M&As or IPOs, will occur more often the higher the duopolists’ prior beliefs, $\lambda$, in combination with low differences in the development costs of a good and a bad idea, as reflected by $\eta_g - \eta_b$, and starting from moderate relative returns to development of the good idea, $\eta_g$.

**Proposition 5** For a bad idea, preemptive acquisitions, instead of IPOs, will occur relatively more often than for a good idea: they happen the more the higher the duopolists’ prior (and wrong) beliefs about the idea being good, $\lambda$, and starting from a relatively high market size, reflected by a low $b$.

**Corollary 2** M&A can be observed:

1. either in the early stages of development, i.e. in the form of preemptive acquisitions, which have a high risk of being associated with a bad idea;

2. or, in late development stages, i.e. after an idea has been developed ad interim by a venture-backed firm, in which case the idea is good and has a relatively high return to development.

Results also give us some predictions about how likely it is that a M&A may turn out not to be profitable for an established firm. In order to be able to judge about how successful M&As might be, as opposed to IPOs, it is necessary to distinguish at which stage an M&A has occurred. Early acquisitions, or preemptive acquisitions, may be inherently riskier than later M&As as they may occur in a point of time when an innovation which is available on the market, has not yet proven to be indeed good. Late acquisitions may be the result of the deliberate choice of firms to wait until the nature of a given innovation is revealed to the market. Without making such a distinction, i.e. without accounting for the potential role that signaling may play in determining the choice for firms to delay the acquisition of a given innovation, M&As may be judged to lead to less successful outcomes. Contrary to Krishnan, Masulis, and Singh (2006), our model therefore predicts that late M&As should be outperforming IPOs systematically. In Krishnan et al., reputed venture capitalists are considered to contribute to successful IPOs which is taken as the most profitable exit mode for venture-backed firms. Our model has shown that it may be in the interest for venture-backed firms to exit the market through a M&A, as the result of a signaling game, any time the innovation they are developing is good and it has a high relative return to development. If the relative return to development, $\eta_g$, is high, which corresponds, for a given marginal development cost, to a large market size, or, for a given market size, to low marginal development costs of a good idea, our model predicts M&As as the most profitable exit mode. High relative return to development ideas lead to more aggressive development, and, therefore, to bigger innovations.
Ideas to be developed for high-tech industries, such as biotech, information technology, or nanotechnology, are often the target of venture capital investment first, before being then sold on the market at later stages of development through M&As. Therefore, the relative use of M&As as opposed to IPOs might simply reflect an exit mode preference by venture-backed firms which is more related to the nature of the innovation to be developed for the market, than to the functioning of the financial market firms face in a given industry. In our model, facilitating IPOs does not necessarily favor more aggressive development into high-tech innovations.

4 Conclusion

Venture-backed firms are considered to be more aggressive in their early stage development of innovations than already established firms in a market. Our theoretical approach is able to give a rationale to this observed behavior. By allowing for the possibility for a venture-backed firm of having superior information about the nature of an idea to be developed in a market, we have shown that the aggressive behavior in the early stage of development of innovation by venture-backed firm may be the result of a signaling game. Venture-backed firms may be pushed to exacerbate the interim investment into its development in order to signal they are developing a good idea, prior to resell it, either through a M&A or an IPO. The overinvestment enhances the value of the venture-backed firm: it increases the profit of being an acquirer in the market, therefore the valuation for acquiring the idea through a M&A after an interim development, and it decreases the profit of being a non-acquirer, as the non-acquirer would face a very aggressive competitor. The incentive for the venture-backed firm to increase this value, may trigger preemptive acquisitions of ideas by firms. We have shown that this happens only for not too high informational advantages of the venture-backed firm and when the development costs associated to a good or a bad idea are not too different.

References


