Venture Capitalists and 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 show that an aggressive interim development into innovative ideas by better informed venture-backed firms is used as a signaling device to enhance their sale price on the market. The aggressive behavior results from the exacerbated overinvestment into the development of good idea as compared to the optimal level an informed firm in the market would have chosen to invest itself, combined with the need to signal a good idea to the market. This overinvestment may trigger preemptive acquisitions of ideas by firms. For a good idea, preemptive acquisitions, instead of late M&As or IPOs, will occur more often the higher the duopolists' prior beliefs about the idea being good, in combination with low differences in the development costs of a good and a bad idea and starting from moderate relative returns to development of the good idea. For a bad idea, preemptive acquisitions, instead of IPOs, will occur relatively more often than for a good idea. This calls for a distinction between early and late M&As which can be observed: 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; 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.

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

JEL codes: C7, D21, D82, L2

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1 Introduction

There is a growing awareness that venture capitalists play an important role in the innovation process[1]. Venture Capitalists often specialize in financing early stage investments of entrepreneurs' ideas, and are considered to provide them with business experience and expertise[2], as well as with better monitoring mechanisms[3]. However, very little has been done in trying to relate venture capitalists and the organization of the innovation industry, i.e. in explaining the way venture-backed firms interact with established firms in a given market where an innovation may be used.

There exists an extensive empirical literature on venture capital and innovation. 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) and 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). This observation is in line with the fact that venture-backed firms often try to enhance their value on the market by investing more aggressively in the development of initial ideas than established firms. The strategy of venture-backed firms seems to correspond to the "*purpose of being bought out in due course*[4]". In fact, mergers and acquisitions, *M&As*, 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 *IPO*s[5], 9% went out of business, while 49% remained private. 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. Typically, venture-backed firms exit around the fifth year of their existence, well before the innovation is commercialized in the market. Finally, 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).

Our model builds on previous work by Norbäck and Persson (2004), who were the first to relate product market interactions and the role of venture capitalists in the innovation process. However, in their model venture-backed firms would come to existence only whenever they would face lower fixed costs of development than established firms. Contrary to their approach, we base our study on the assumption that venture-backed firms are better informed than established firms when developing a given idea prior to commercializing it for

[1] See, e.g., Gompers and Lerner (2001).

[2] Hellmann and Puri (2002) find evidence of US Venture Capital being related to a variety of professional measures, Bottazzi, Da Rin, and Hellmann (2004) find similar evidence for European Venture Capital.

[3] Kaplan and Strömberg (2001) show that venture capitalists can mitigate the principal-agent conflicts.

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

[5] Initial Public Offerings

the market. This assumption corresponds to the empirically observed evidence of venture capitalists playing an active role in the selection and early stage development of ideas prior to their commercialization in the market.

The ability to select highly innovative ideas by venture capitalists may be due to the presence of superior information about the nature of the idea to be developed. 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. In addition to this, even if only the entrepreneur was fully informed about the nature of the idea, whenever he would team up with the venture capitalist he would have an incentive to truthfully reveal it to him, so that the venture-backed firm will ultimately share the same information about the nature of the idea. The reason for this is that letting the venture capitalist have the same information as the entrepreneur would improve the entrepreneur's ability to extract more from the sale of an idea he might come up with. When established firms face the threat that a venture capitalist might team up with the entrepreneur for developing a given idea, they may be forced to pay a higher price to appropriate the idea than otherwise, which may make it too costly for them to get the idea to be developed in the first place. When, in addition, established uninformed firms face the threat of an informed venture capitalist who might team up with the entrepreneur, these firms might have a reduced ability to appropriate the idea as compared to the situation where there is no asymmetry of information. If the entrepreneur could choose to perfectly inform firms on the market about the innovative nature of an idea to be sold, he would be better off as compared to keeping only the venture capitalist informed about it. However, the entrepreneur may not want to transfer this knowledge about how good and how bad an idea is to established firms, for example because the rights on the development on this idea are not fully protected and the entrepreneur fears that by revealing the nature of the idea and all its characteristics for development the idea could be stolen by the established firms on the market. The knowledge about the idea being good or bad, even if potentially perfectly transferable, is not desirable by the entrepreneur in this case. Let us suppose that an entrepreneur comes up with an idea and decides to go to any of the established firms in the market and reveal his idea to it. Full revelation of the characteristics of the idea to these firms, even if possible, and prior to its sale could lead to the danger of stealing this idea, which may explain why the entrepreneur in an attempt to protect his rights on the development of the idea may prefer to give some fuzzy indications about how good the idea might be for its development for the market, and keep the rest of the information for himself. Instead, the entrepreneur would want to share his information with the venture capitalist as by doing so he does not fear the risk of expropriation of his idea. If the idea is valuable, either because it is indeed good or because even if it is bad it might still be resold on the market afterwards for a high enough value, it will be in the interest of the venture capitalist to appropriate it and of the entrepreneur to team up with the venture capitalist instead of selling the idea to uninformed firms on the market. An alternative

reason for thinking that venture-backed firms may have superior information as compared to the rest of the market is that the knowledge about the innovative nature of a given idea is an implicit one. If there exists a tacit knowledge about the development of the idea, we may envisage situations where the entrepreneur and the venture capitalist are simply better at assessing the potential of a very new idea and, as a result, they end up sharing the same tacit information about the idea to be developed for the market.

This paper combines the venture capitalists' superior ability to select good ideas with their role in the organization of the innovation process, thereby providing a theoretical model for the existence of venture capitalists in this process. This way we are able to describe which is the preferred mode of exit by venture-backed firms, as well as their observed aggressive investment strategies into the development of highly innovative ideas. We show that venture-backed firms by signaling the nature of innovations to potential acquirers in the market are able to solve for an asymmetry of information linked to the inability of the established firms to assess the profitability of new ideas. Costly but productive signaling and product market interaction of acquirers and non-acquirers are ultimately responsible for the venture-backed firm's overinvestment into the interim development of ideas. We show that late *M&As* are associated with high overinvestments and, therefore, competition between a very aggressive acquirer of an innovation and the non-acquirers in the final product market. Early acquisitions on the other hand, are more often associated with bad ideas, as incumbents are unable to make use of the information a venture capitalist could have provided otherwise by signaling. Established firms face 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*) involves first 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 on the final market; and, second, having to pay a higher price for acquiring an idea which has been overdeveloped by the venture-backed firm.

Our model suggests that it is important to distinguish between early stage *M&As* and late *M&As*. Early acquisitions, or preemptive acquisitions, in our model will be associated with an higher risk in selecting good or bad ideas to be further developed for the market. Late acquisitions instead may provide the opportunity for established firms to learn whether an idea is good for development and, therefore, may be preferred over early acquisitions. We will show that it is 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. High relative return to development ideas lead to more aggressive development, and, therefore, to bigger innovations. Big innovations are therefore associated with

ideas which were first the targets of venture capitalists, then were subject to interim development and then were sold on the market through *M&As* more often than less innovative ideas which, if developed within a venture-backed firm, are instead exited through *IPOs*. These findings are in line with the observation that 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*. The relative use of *M&As* as opposed to *IPOs* might then simply reflect a preference by venture-backed firms about the mode of exit which is more related to the nature of the innovation to be developed for the market, than to the a more or less well functioning financial market firms face in a given industry. Facilitating *IPOs* is not necessarily conducive to more high-tech innovation.

Our model gives more precise predictions as to in which industry, or in which economic environment, we should observe early stage *M&As*, and in-house development by established firms on a market, as opposed to venture-backed interim developments followed by either *M&As* or *IPOs*.

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. Section 4 concludes the paper.

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*, 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 good idea, a costly investment of size $x \geq 0$ in its development leads to a unit production cost reduction of $\Delta = x$ - or to an increase in the quality of the product of $\Delta = x$ - whereas for a bad one, any investment leads to $\Delta = 0$. Ideas here stand for any invention or innovation an entrepreneur might come up with, which may or not have a potential for development in a given market where established firms are already competing. Good ideas are associated with high potentials for their exploitation - either in terms of process or product innovation - while bad ideas are the ones which are not suitable for further development no matter how much investment could be put into them. Basically, bad ideas are the ones which may be very costly to develop for a given market, or for a given process - depending on whether we adopt the product or the process innovation perspective. It is difficult to adapt them to a given product - or to a given process - no matter how many resources could be put into their development. Therefore, good and bad ideas in our model will

also be associated respectively with *less* or *more resource demanding development technologies*[6].

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

[6] We will describe more in detail the specific development cost function we adopt in our model in the rest of this section.

capitalist, the venture-backed firm may invest in an *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 *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 verifiable* by both the duopolists and the potential buyers in an *IPO,* and *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.

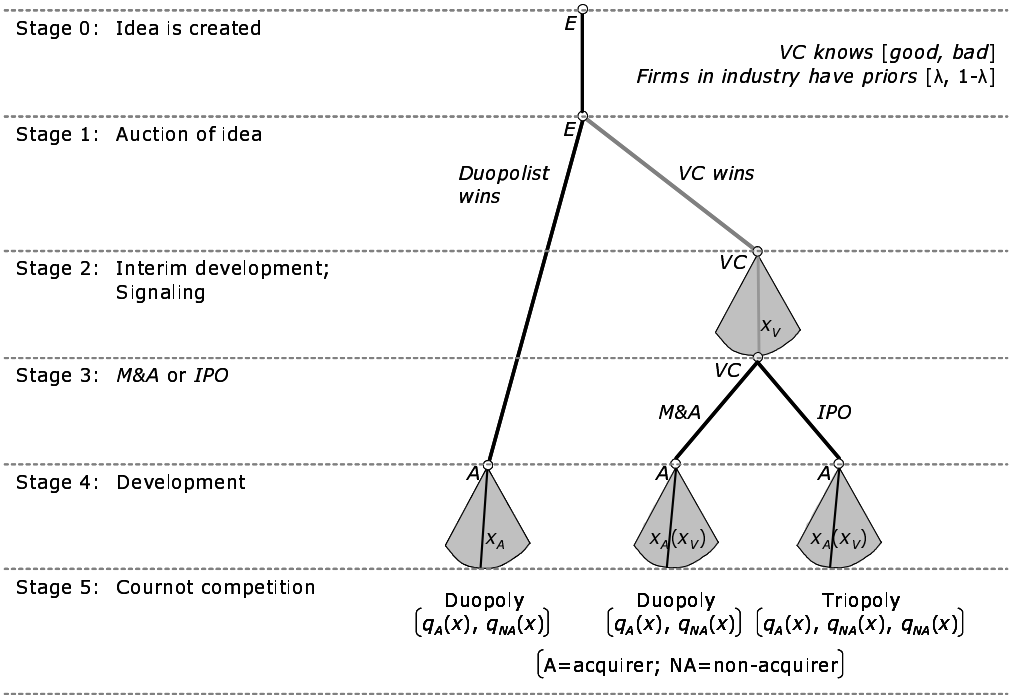

Figure 1: Timing

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 λ 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[7].

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.

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

[7] 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.

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*:

$$q_A^{D,g}(x) = \frac{a-c+2x}{3b}, \tag{1}$$

$$q_{NA}^{D,g}(x) = \frac{a-c-x}{3b}. \tag{2}$$

These are the optimal quantities when two firms compete, but one of them has a cost advantage over the other[8].

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

$$\pi_A^{D,g}(x) = b\left(\frac{a-c+2x}{3b}\right)^2, \tag{3}$$

$$\pi_{NA}^{D,g}(x) = b\left(\frac{a-c-x}{3b}\right)^2. \tag{4}$$

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:

$$q_A^{D,b} = q_{NA}^{D,b} = \frac{a-c}{3b}. \tag{5}$$

The associated product market profits are:

$$\pi_A^{D,b} = \pi_{NA}^{D,b} = b\left(\frac{a-c}{3b}\right)^2. \tag{6}$$

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[9] 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.

[8] 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.

[9] *IPOs* might be solving for some lack of coordination among dispersed potential shareholders.

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:

$$q_A^{T,g}(x) = \frac{a-c+3x}{4b}, \tag{7}$$

$$q_{NA}^{T,g}(x) = \frac{a-c-x}{4b}. \tag{8}$$

These quantities will lead to the following product market profits:

$$\pi_A^{T,g}(x) = b\left(\frac{a-c+3x}{4b}\right)^2, \tag{9}$$

$$\pi_{NA}^{T,g}(x) = b\left(\frac{a-c-x}{4b}\right)^2. \tag{10}$$

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

$$q_A^{T,b} = q_{NA}^{T,b} = \frac{a-c}{4b}. \tag{11}$$

The associated product market profits are:

$$\pi_A^{T,b} = \pi_{NA}^{T,b} = b\left(\frac{a-c}{4b}\right)^2. \tag{12}$$

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.

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:

$$\max_{x_A}\left[\lambda\left(\pi_A^{D,g}(x)-\frac{\mu_g x_A^2}{2}\right)+(1-\lambda)\left(\pi_A^{D,b}(x)-\frac{\mu_b x_A^2}{2}\right)\right], \tag{13}$$

i.e. he maximizes the expected gross[10] 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[11]:

$$x^{\lambda}=\frac{4\lambda(a-c)}{9\left((1-\lambda)b\mu_b+\lambda b\mu_g\right)-8\lambda} \tag{14}$$

The profit maximizing investment x^{λ} equals the overall investment made into the development of an idea in this particular case[12].

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

$$\begin{aligned} E\Pi^D\left(x^{\lambda}\right) &= \lambda\left(\pi_A^{D,g}\left(x^{\lambda}\right)-\frac{\mu_g\left(x^{\lambda}\right)^2}{2}\right)+(1-\lambda)\left(\pi_A^{D,b}\left(x^{\lambda}\right)-\frac{\mu_b\left(x^{\lambda}\right)^2}{2}\right) \\ &= (a-c)^2\frac{1}{b}\frac{\left((1-\lambda)(8\lambda-9b\mu_b)-9\lambda b\mu_g\right)}{9\left(\lambda\left(8+9b\mu_b-9b\mu_g\right)-9b\mu_b\right)} \end{aligned} \tag{15}$$

Notice that if the duopolist acquiring the idea had perfect information about the idea being good[13], i.e. if $\lambda=1$, then his optimal investment level into the development of this good idea, and its associated product market profits, would have been:

$$x^{\lambda} = \frac{4(a-c)}{9b\mu_g-8}, \tag{16}$$

$$\pi_A^{D,g}\left(x^{\lambda}\right)-\frac{\mu_g\left(x^{\lambda}\right)^2}{2} = \frac{\mu_g(a-c)^2}{9b\mu_g-8}. \tag{17}$$

Instead, had the duopolists shared the prior that the idea offered on the market is a bad one, i.e. if $\lambda=0$,

[10] Gross of the bid that has been paid in order to get the idea to be developed at first.

[11] Therefore we have labelled this investment as x^{λ} 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.

[12] Remember 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.

[13] Either 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.

no investment into its development would have been made at all. So that:

$$\begin{aligned} x^{\lambda} &= 0, \\ \pi_A^{D,b}\left(x^{\lambda}\right) - \frac{\mu_b\left(x^{\lambda}\right)^2}{2} &= b\left(\frac{a-c}{3b}\right)^2. \end{aligned} \tag{18}$$

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:

$$\max_{x_A}\left[\pi_A^{D,g}\left(x_A + x_V\right) - \left(\frac{\mu_g\left(x_V + x_A\right)^2}{2} - \frac{\mu_g x_V^2}{2}\right)\right]. \tag{19}$$

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

$$x_A^{D,g}\left(x_V\right) = \begin{cases} \frac{4(a-c)}{9b\mu_g - 8} - x_V & \text{if } x_V < \frac{4(a-c)}{9b\mu_g - 8}, \\ 0 & \text{otherwise.} \end{cases} \tag{20}$$

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:

$$x^{D,g} = x_A^{D,g}\left(x_V\right) + x_V. \tag{21}$$

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:

$$\max_{x_A}\left[\pi_A^{T,g}\left(x_A+x_V\right)-\left(\frac{\mu_g\left(x_V+x_A\right)^2}{2}-\frac{\mu_g x_V^2}{2}\right)\right]. \tag{22}$$

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

$$x_A^{T,g}\left(x_V\right)=\begin{cases}\frac{3(a-c)}{8b\mu_g-9}-x_V & \text{if } x_V<\frac{3(a-c)}{8b\mu_g-9},\\ 0 & \text{otherwise.}\end{cases} \tag{23}$$

The total investment in this case is:

$$x^{T,g}=x_A^{T,g}\left(x_V\right)+x_V \tag{24}$$

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&A* or *IPO*

Proceeding backwards, we will have to determine under which conditions a venture-backed firm prefers to exit the market through a *M&A* 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&A* 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&A*

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:

$$S_3^{D,g} = \pi_A^{D,g}\left(x^{D,g}\right) - \left(\frac{\mu_g\left(x_A^{D,g}\left(x_V\right) + x_V\right)^2}{2} - \frac{\mu_g x_V^2}{2}\right) - \pi_{NA}^{D,g}\left(x^{D,g}\right), \tag{25}$$

where $S_3^{D,g}$ is the sale price of a venture-backed firm *in stage 3* after the interim development of a good idea has been made[14]. 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.

If the partially developed idea is good, then the funds which can be raised are given by:

$$S_3^{T,g} = \pi_A^{T,g}\left(x^{T,g}\right) - \left(\frac{\mu_g\left(x_A^{T,g}\left(x_V\right) + x_V\right)^2}{2} - \frac{\mu_g x_V^2}{2}\right), \tag{26}$$

[14] Going to one of the duopolist 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.

where $S_3^{T,g}$ 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.:

$$S_3^{T,b} = \pi_A^{T,b}, \tag{27}$$

where $S_3^{T,b}$ 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*, $x_V^{D,g}$, such that:

$$x_V^{D,g} = \arg\max_{x_V} \left\{ S_3^{D,g} - \frac{\mu_g x_V^2}{2} \right\} = \frac{2\,(a-c)}{3b\mu_g - 2}. \tag{28}$$

Note that:

$$x_V^{D,g} = \frac{2\,(a-c)}{3b\mu_g - 2} \equiv \frac{2\eta_g\,(a-c)}{3-2\eta_g} > \frac{4\eta_g\,(a-c)}{9-8\eta_g} \equiv \frac{4\,(a-c)}{9b\mu_g - 8} = x_A^{D,g}\,(0) \Leftrightarrow \eta_g < \frac{3}{4}, \tag{29}$$

where $\eta_g = \frac{1}{b\mu_g}$ can be interpreted as the *relative return to development of a good idea*[15] (increasing in market size $\frac{1}{b}$ and decreasing in development costs μ_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:

$$\Pi_V^{D,g} = \frac{2\,(a-c)^2}{b\left(9b\mu_g - 6\right)}. \tag{30}$$

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:

$$S_3^{D,g} - \frac{\mu_b \left(x_V^{D,g}\right)^2}{2} < 0 \Leftrightarrow \eta_b < \frac{3\eta_g}{6-2\eta_g}, \tag{31}$$

[15] A high η_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.

where $\eta_b = \frac{1}{b\mu_b}$. 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:

$$\begin{aligned} x_V^{D,s} &= \left\{ x_V \left| S_3^{D,g} - \frac{\mu_b \left(x_V\right)^2}{2} = 0 \right. \right\} \\ &= 4\frac{(a-c)}{3b\mu_b - 2} \equiv 4\eta_b \frac{(a-c)}{3-2\eta_b}, \end{aligned} \tag{32}$$

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:

$$\Pi_V^{D,s} = \frac{8(\mu_b - \mu_g)\left(a-c\right)^2}{\left(3b\mu_b - 2\right)^2}. \tag{33}$$

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* $\eta_b < \frac{3\eta_g}{6-2\eta_g}$*; and a constrained interim development,* $x_V^{D,s} > x_V^{D,g}$*, 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:

$$x_V^{T,g} = \arg\max_{x_V} \left\{ S_3^{T,g}(x_V) - \frac{\mu_g x_V^2}{2} \right\} = \frac{3(a-c)}{8b\mu_g - 9}. \tag{34}$$

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[16].

[16] Both 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.

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

$$\Pi_V^{T,g} = \frac{\mu_g (a-c)^2}{2\left(8b\mu_g - 9\right)}. \tag{35}$$

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:

$$S_3^{T,g} - \frac{\mu_b \left(x_V^{T,g}\right)^2}{2} < S_3^{T,b} \Leftrightarrow \eta_b < \frac{8\eta_g}{16 - 9\eta_g}. \tag{36}$$

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:

$$\begin{aligned} x_V^{T,s} &= \left\{ x_V \left| S_3^{T,g} - \frac{\mu_b (x_V)^2}{2} = S_3^{T,b} \right. \right\} \\ &= \frac{6(a-c)}{8b\mu_b - 9}, \end{aligned} \tag{37}$$

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:

$$\Pi_V^{T,s} = \frac{(a-c)^2}{16b} \frac{(8b\mu_b + 9)^2 - 288b\mu_g}{(8b\mu_b - 9)^2}. \tag{38}$$

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&A* 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&A* 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&A* 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&A* 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 $\left\{ \{\eta_b, \eta_g\} \middle| \eta_b < \frac{3\eta_g}{6-2\eta_g} \right\} \supseteq \left\{ \{\eta_b, \eta_g\} \middle| \eta_b < \frac{8\eta_g}{16-9\eta_g} \right\}$.

Proof. $\forall \eta_g$, $\frac{3\eta_g}{6-2\eta_g} < \frac{8\eta_g}{16-9\eta_g}$. ■

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&A* 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&A* 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&A* the venture-backed firm's net gains are:

$$\Pi_V^D = \begin{cases} \Pi_V^{D,g} = \frac{2(a-c)^2}{b\left(9b\mu_g - 6\right)} & \text{if} \quad \eta_b < \frac{3\eta_g}{6-2\eta_g} \\ \Pi_V^{D,s} = \frac{8(\mu_b - \mu_g)(a-c)^2}{(3b\mu_b - 2)^2} & \text{if} \quad \eta_b \geq \frac{3\eta_g}{6-2\eta_g} \end{cases}, \tag{39}$$

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

$$\Pi_V^T = \begin{cases} \Pi_V^{T,g} = \frac{\mu_g (a-c)^2}{2\left(8b\mu_g - 9\right)} & \text{if} \quad \eta_b < \frac{8\eta_g}{16-9\eta_g} \\ \Pi_V^{T,s} = \frac{(a-c)^2}{16b} \frac{(8b\mu_b + 9)^2 - 288b\mu_g}{(8b\mu_b - 9)^2} & \text{if} \quad \eta_b \geq \frac{8\eta_g}{16-9\eta_g} \end{cases}. \tag{40}$$

We can now proceed with the relevant comparisons in terms of profitability of one exit mode over the other one for the venture-backed firm.

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

$$\Pi_V^{D,s} > \Pi_V^{T,s}. \tag{41}$$

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

$$\Pi_V^{D,s} > \Pi_V^{T,g}. \tag{42}$$

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

$$\Pi_V^{D,g} > \Pi_V^{T,g}. \tag{43}$$

These inequalities, which reduce to conditions on η_g and η_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.

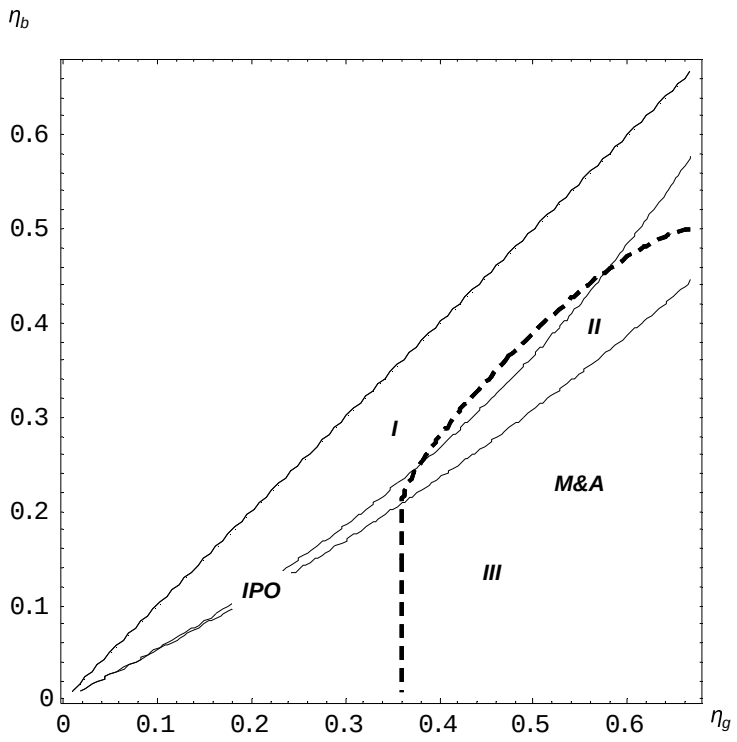

Figure 2: Which exit mode: *M&A* or *IPO*?

Note that in figure 2 we restrict the parameters η_b and η_g to vary over the interval $\left[0, \frac{2}{3}\right]$. 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, η_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 ε[17]. 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:

$$E\Pi^D\left(x^\lambda\right) = \lambda\left(\pi_A^{D,g}\left(x^\lambda\right) - \frac{\mu_g\left(x^\lambda\right)^2}{2}\right) + (1-\lambda)\left(\pi_A^{D,b}\left(x^\lambda\right) - \frac{\mu_b\left(x^\lambda\right)^2}{2}\right). \tag{44}$$

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 be obtained by the other duopolist in *stage 1*, $v_{A1}^{D1}\left(x^\lambda\right)$, corresponds to:

$$v_{A1}^{D1}\left(x^\lambda\right) = E\Pi^D\left(x^\lambda\right) - \lambda\pi_{NA}^{D,g}\left(x^\lambda\right) - (1-\lambda)\,\pi_{NA}^{D,b}\left(x^\lambda\right). \tag{45}$$

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*, $v_{A1}^{D3}\left(x_V^{D,g}\right)$, corresponds to:

$$v_{A1}^{D3}\left(x_V^{D,g}\right) = E\Pi^D\left(x^\lambda\right) - \lambda\pi_{NA}^{D,g}\left(x_V^{D,g}\right) - (1-\lambda)\,\pi_{NA}^{T,b}. \tag{46}$$

[17] 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*.

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*, $v_{A1}^{D3}\left(x_V^{D,s}\right)$, corresponds to:

$$v_{A1}^{D3}\left(x_V^{D,s}\right) = E\Pi^D\left(x^\lambda\right) - \lambda\pi_{NA}^{D,g}\left(x_V^{D,s}\right) - (1-\lambda)\,\pi_{NA}^{T,b}. \tag{47}$$

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 unconstrained in its signaling, and then exits the market by going public in *stage 3*, $v_{A1}^{T3}\left(x_V^{T,g}\right)$, corresponds to:

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

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*, $v_{A1}^{T3}\left(x_V^{T,s}\right)$, corresponds to:

$$v_{A1}^{T3}\left(x_V^{T,s}\right) = E\Pi^D\left(x^\lambda\right) - \lambda\pi_{NA}^{T,g}\left(x_V^{T,s}\right) - (1-\lambda)\,\pi_{NA}^{T,b}. \tag{49}$$

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

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

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

$$v_{V1}^{D,g} = \Pi_V^{D,g} = \frac{2\left(a-c\right)^2}{b\left(9b\mu_g - 6\right)}, \tag{51}$$

$$v_{V1}^{D,s} = \Pi_V^{D,s} = \frac{8(\mu_b - \mu_g)\left(a-c\right)^2}{\left(3b\mu_b - 2\right)^2}, \tag{52}$$

$$v_{V1}^{T,g} = \Pi_V^{T,g} = \frac{\mu_g\left(a-c\right)^2}{2\left(8b\mu_g - 9\right)}, \tag{53}$$

$$v_{V1}^{T,s} = \Pi_V^{T,s} = \frac{\left(a-c\right)^2}{16b}\frac{\left(8b\mu_b + 9\right)^2 - 288b\mu_g}{\left(8b\mu_b - 9\right)^2}. \tag{54}$$

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: $\eta_b \leq \frac{3\eta_g}{6-2\eta_g}$ 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

$$v_{A1}^{D3}\left(x_V^{D,g}\right) > v_{V1}^{D,g}. \tag{55}$$

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 unconstrained 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

$$v_{A1}^{T3}\left(x_V^{T,g}\right) > v_{V1}^{T,g}. \tag{56}$$

Case 2: $\frac{3\eta_g}{6-2\eta_g} < \eta_b \leq \frac{8\eta_g}{16-9\eta_g}$ 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:

$$v_{A1}^{D3}\left(x_V^{D,s}\right) > v_{V1}^{D,s}. \tag{57}$$

For $\Pi_V^{D,s} \leq \Pi_V^{T,g}$, 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&A*. We would observe *preemptive acquisitions* any time

$$v_{A1}^{T3}\left(x_V^{T,g}\right) > v_{V1}^{T,g}. \tag{58}$$

Case 3: $\frac{8\eta_g}{16-9\eta_g} < \eta_b$ Here, the unconstrained interim development levels are incentive compatible neither for a *M&A* 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&A* instead of the one associated with an *IPO*. As before, this would lead to *preemptive acquisitions* any time the following holds:

$$v_{A1}^{D3}\left(x_V^{D,s}\right) > v_{V1}^{D,s}. \tag{59}$$

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&A*. Therefore, *preemptive acquisitions* will be observed for this case as long as

$$v_{A1}^{T3}\left(x_V^{T,s}\right) > v_{V1}^{T,s}. \tag{60}$$

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&As* 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 λ 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[18]. 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.

[18] 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.

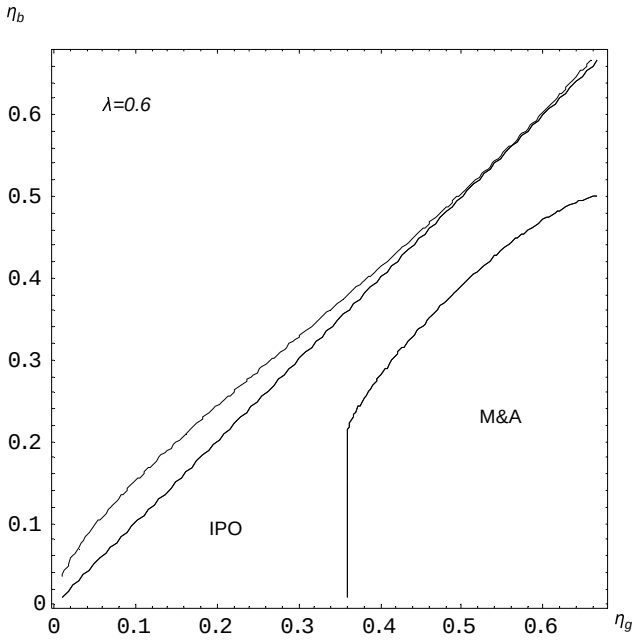

Figure 3: Equilibrium for a good idea when $\lambda = 0.6$

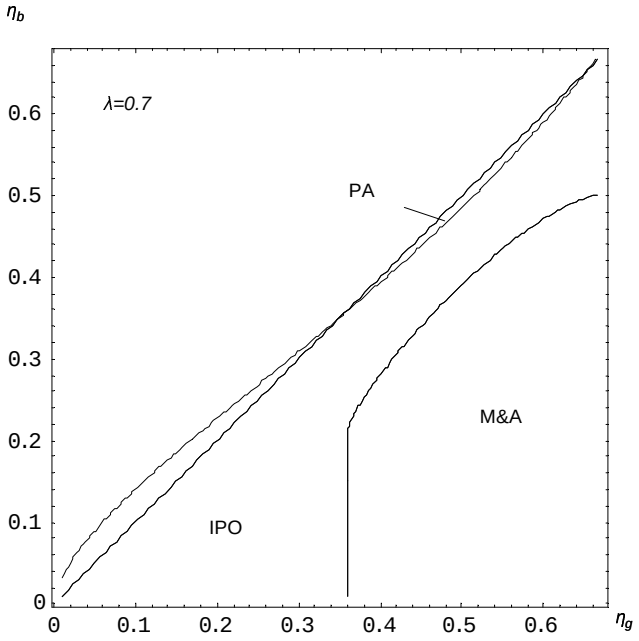

Figure 4: Equilibrium for a good idea when $\lambda = 0.7$

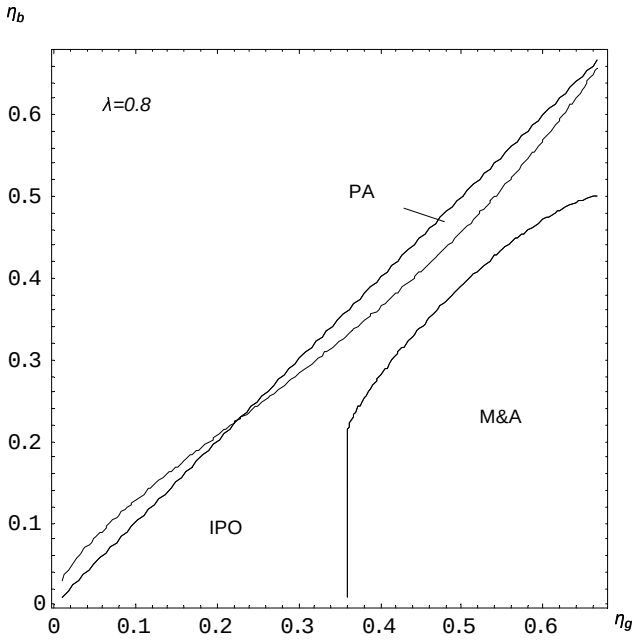

Figure 5: Equilibrium for a good idea when $\lambda = 0.8$

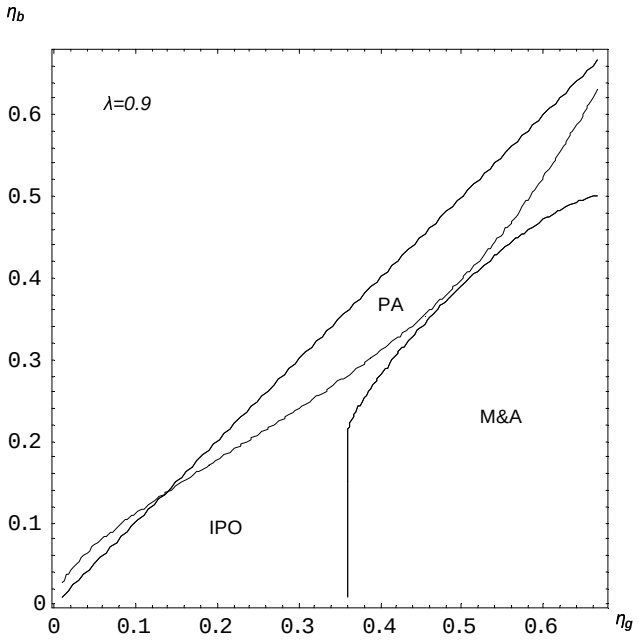

Figure 6: Equilibrium for a good idea when $\lambda = 0.9$

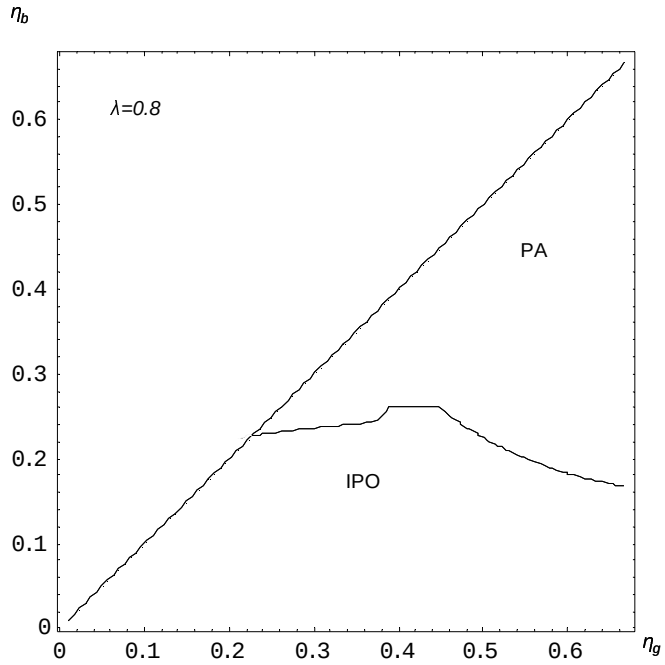

Figure 7: Equilibrium when idea is bad for $\lambda = 0.8$

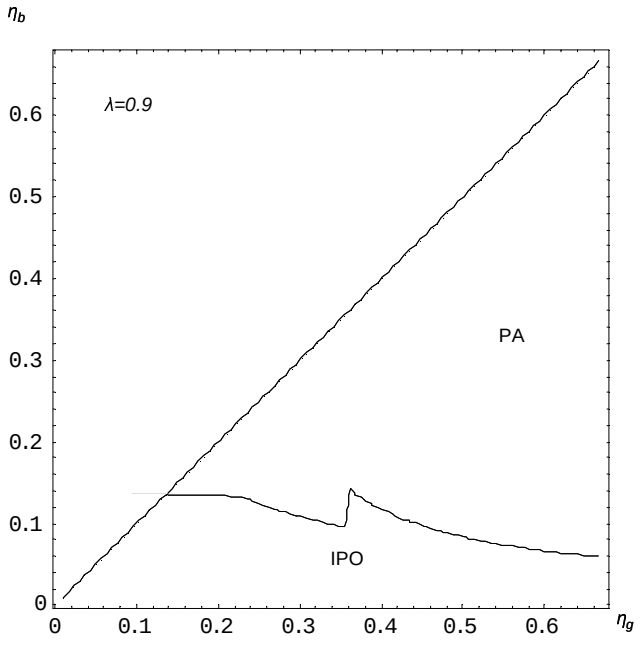

Figure 8: Equilibrium for a bad idea when $\lambda = 0.9$

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 , λ, 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, η_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, λ, 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, η_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.

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