Venture-backed IPOs
– grandstanding and clustering

by

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Abstract

The previous theoretical literature on IPOs has been carried out under the assumption of a free supply of new issues, emphasizing how the valuation and magnitude of new issues can be explained by mechanisms on the demand side. This model explains grandstanding and IPO clusterings based on supply side dynamics and adverse selection between venture capitalists and their investors. We derive the optimal divestment pattern of venture capitalists in the process of gaining reputation. From this we show how grandstanding and IPO clusterings are linked to financial constraints, and how competition for funding strengthens this results. Finally, we argue that the social loss in this context has three mayor components. Besides under- and overinvestment in new funds, some companies are divested too soon, in order for venture capitalists to signal good ability of project selection.

Some illustrations are in colors. Please use color printer

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1 Introduction

We develop a model to show that adverse selection in limited partnerships can account for two of the most predominant features of venture capital: the clusterings of initial public offerings (IPOs) and the grandstanding of new venture capitalists. We extend the existing framework and understanding of primary market mechanisms in order to analyze the supply of new issues. A dominating assumption in the existing literature is that new issues are in free supply. This implies that any phenomenon (such as clustering) is explained by changes on the demand side only, the most important of these being informational spillovers. To this end, the literature has only one side of the economics of IPOs, namely the mechanisms on the demand side. The timing of IPOs, their magnitude and relation to the dynamics of venture capital funds, from which a large part of new issues stem, are yet to be covered. Our model offers a first analysis of the relationship between the timing of IPOs and venture capitalists' (VCs') attempts to gain reputation and signal ability (quality) to create highly valuable new enterprises.

We incorporate one of the most profound features of the VC's decision problem in the course of an IPO: in order to stay active in the industry, she must at all times take into account her financial constraint in the funding of new ventures.[1] The VC relies on an access to funds that are provided by a group of investors, who cannot monitor her actions. This means that the access to funds on a large scale will be determined by some evaluation of her past performance. An obvious evaluation is based on the previous returns generated from her existing portfolio, which means that by divesting, she is exposed to two types of risk: i) the risk of a divested company failing, which relates to the financial market's valuation of the new issue, and ii) the risk of not getting funded (henceforth denoted the *constraining risk*). Assuming that the investors only observes past returns, the VC is faced with the following problem. If she knows that no funding can be obtained based upon the investor's prior beliefs, she must divest off existing ventures. Without adverse selection, the timing of this divestment would be given based on IPO forecasts, earning potentials, etc.; i.e. based on specific information about each venture. Adding a constraining risk to the VC's problem means that existing ventures are divested prematurely, yielding a depreciation in value relative to each venture's true

[1] We refer to the VC as *she*, and to the investor as *he*.

potential. This renders her with an optimal stopping problem in which expected gains from obtaining new funding trade off expected losses due to depreciated ventures. This tradeoff is analyzed in its most simple form with risk neutral agents, no time-discounting, fixed equity contracting, and Bernoulli distributed returns on new investments. However, these assumptions are not critical, and our presentation is followed up by a thorough discussion of some interesting extensions of our basic setting. In our model, we can separate the influences of investors' anticipation of VCs, and the quality of potential ventures (new investments). We can predict how these are related to VCs' decision problems and how the overall divestment patterns correspond to changes in these factors (resp. externally and internally). External factors include the distribution of good and bad VCs and their success probabilities. As expected, we find a monotonically positive relationship between the fraction of good VCs and the overall funding probability. The same holds true for increments in the success probability of good VCs. For bad VCs this relationship is non-monotonic since the risk of rejecting a good VC outweighs the risk of funding a bad one, as explained below. Our result is driven by the VC's need to signal personal quality to the investor. The analysis is carried out in the presence of adverse selection, but could be extended to consider moral hazard issues by extending the contractual setup. We are able to elaborate on the inefficiencies in the venture industry and split up the aggregated social loss into three categories: i) the generic signaling cost held by VCs (which to some extent could have macro effects as explained below), ii) the risk of rejecting highly qualified VCs, and iii) the risk of funding under-qualified VCs. Each type of social inefficiency is related to the external and internal factors. Finally, we show how IPO clusterings and the grandstanding behavior of young VCs can be explained in the context of our model.

Literature review

Our paper extends our understanding of venture-backed IPOs and explains commonly observed divestment patterns for VC-firms. Empirical studies of IPOs have shown two prevailing phenomenons: *underpricing* and *clustering* of new issues. Underpricing has been documented and analyzed in several studies, e.g. Logue (1973), Ibbotson (1975), Ibbotson and Jaffe (1975), and more recently in for instance Brau and Fawcett (2006), Aruğaslan et al. (2004), and Smart and Zutter (2003). The explanations range from i) Asymmetric information theories such as Rock (1986) and Beatty and Ritter (1986), where uninformed investors suffer a *winner's curse* when purchasing unattractive issues, over ii) Institutional theories, which use litigation, price stabilizing (once the issue is offered), and taxes, as the main explanation, which dates back to the work of Logue and Ibbotson, and iii) Control theories, which argue that underpricing can be understood as the VC's attempt to avoid outside control, hence losing private benefits from non-profit maximizing actions, like Brennan and Franks (1997), to iv) Behavioral theories suggesting that irrational investors, or behavioral biases can account for the underpricing.

In the analysis of IPO clusterings, the asymmetric information approach is commonly used. The idea is that once a company goes public, the market receives new information relevant not only for pricing the company itself, but for similar new issues as well; for instance, information about earning potentials and costs in the industry. With this updating posterior to an IPO, the prospects of going public for the next company might have changed to its advantage; see Benninga et al. (2005). This is referred to as the *informational spillover* in the primary market, and to this end spillover effects have been the common explanation for IPO clusterings. Since a large part of these new public companies have been backed by venture capital until the IPO, and since in many cases the IPO decision will be made (or strongly influenced) by a VC—as in Schmidt (2003)—the IPO decision will not only be determined by internal conditions in the company being offered, but also by conditions solely related to the VC, such as future funding prospects. The attention to the institutional context of the agents in the IPO process is shared in the empirical analysis of Alavi et al. (2008), who find a significant influence of pre-IPO ownership in the course of a public offering. Further, Lin et al. (2007) show that institutional context has an important effect in the primary market as well. The VC's participation in her portfolio companies involves advising and monitoring, and in many cases she is represented on the board of directors and among the CEO's associates as well. The optimality of this engagement has been analyzed by Casamatta (2003). To keep the focus on supply side dynamics, we assume that the magnitude of new ventures does not influence the initial price of each share, and spillover effects are omitted as well. Although these features could be added to the setting, we have chosen not to, in order to keep the model as simple as possible. Our approach differs from the existing literature in its focus on the supply of new issues, and we take into account that new issues are not always offered by entrepreneurs in search of equity funding, but by VCs divesting their portfolios. Since VCs (per se) are repeated players in a bargain for funding of new ventures, their incentives must be taken into account when analyzing IPO clusterings.

Our model supplements the existing literature on the role of VCs in the IPO process. The key observation is that VCs are repeated players in the industry, thus relying on a reputation for not exploiting informational advantages over the primary market. Booth and Smith (1986) expand the idea of reputational signaling to explain how underwriters certify project value in the capital raising process and their result is referred to as the *certification hypothesis*.[2] Meggison and Weiss (1991) explain a relatively low underpricing of venture-backed IPOs by the certifying role of VCs. Since the VC knows that exploiting an informational advantage today would decrease any future returns from IPOs, and since the primary market anticipates this, a separating equilibrium is reached and the new shares are offered at their intrinsic value. A related branch of models emphasizes the monitoring role of VCs (Barry et al., 1990) and their ability to attract large institutional investors to the primary market (Chemmanur and Loutskina, 2006). All of these features that derive from reputational signaling have an impact on the IPO process. In early empirical studies, such as Barry et al. (1990) and Meggison and Weiss (1991), reputational signaling (either in form of certification or monitoring) was highlighted as the explanation for venture-backed IPOs being offered closer to their intrinsic value (less underpricing), simply because the primary market knows that the VC would never jeopardize her reputation; however, later studies such as Lee and Wahal (2004) and Loughran and Ritter (2003) show that venture-backed IPOs in general are not less underpriced than other IPOs. So not only do we have a disagreement regarding the nature of reputational signaling, but its importance for the pricing in the primary market seems to present some time inconsistencies as well. To this end we have not reached a satisfactory unifying model for the influence of VCs in the IPO process. To keep the analysis simple, models such as Booth and Smith (1986) assume that the certification is perfect in the sense that

[2] Originally formulated in Klein and Leffler (1981).

the underwriter is never misunderstood (there is no exogenous risk). In the IPO process this means that the VC must have all information relevant for the pricing of the new issue; i.e. she foresees the primary market's response. This is of course not the case in reality, and a formal model of reputational signaling in venture capital should address this incompleteness. Another important aspect that has received no theoretical investigation is how reputation is gained and how the process of doing so influences venture capitalists' decision making. As recognized by Gompers (1996), young VCs act relatively aggressively in order to gain territory in the industry and to signal their qualities to the financial markets; grandstanding has subsequently been documented in several studies. The present model offers an explanation of this behavior based on the fact that in an environment where certification (or a similar reputational signaling) is not possible and the IPO process is risky, VCs signal their qualities through specific IPO paths. The results link to both the grandstanding phenomenon and to the clustering of new issues. We consider two cases: i) a monopoly (1 VC) where clusterings are analyzed at the fund level, and ii) a duopoly (2 VCs) that illustrates how competition for funding induces clustering at the industry level. Linking a VC's lack of reputation to a more aggressive divestment strategy helps us understand the grandstanding behavior of young VCs in greater detail.

The paper is organized as follows. Section 2 sets up the basic model. Section 3 considers several extensions and Section 4 concludes. All proofs are presented in the appendix.

2 The Model

This section sets up the basic model and the information structure as well as introduces the agents and their decision problems. The notion of constraining risk is presented, along with its link to the evaluation of past performance. We show that the VC has an optimal stopping problem in the course of divestments, and combine this with the investor's decision problem and analyze properties of the equilibrium. The section is divided into three parts: Firstly, the basic model is established, and some of its features are analyzed (2.1-2.3). Secondly, we introduce the divestment density and relate the amount of divested ventures to the social optimum to illustrate how clustered issues link to the efficiency of private equity

(2.4-2.5). Finally, the model is extended to analyze the impact of competition and to give explicit predictions about the grandstanding phenomenon as well as a new intuition for how IPO clusterings can be explained by funding limitations (2.6).[3]

2.1 Setup

We consider a model with two agents, a VC and an investor. Both are risk neutral, and there is no discounting. Initially, the VC holds a portfolio of N ventures, $\{v^i\}_{i=1}^N$, and an investment opportunity that requires an outlay, K. She is assumed to be unendowed, and whether K will be provided is determined by the investor, based on the information about the realized returns of prior divestments; i.e. K is provided if her private-placement memorandum provides a strong signal of her qualities.[4] There are two types of VCs, $q \in \{q_B, q_G\}$ (Bad and Good), and the investor's prior beliefs are $\mathbb{P}(q = q_G) = \gamma$. We will throughout make the assumption that any return is split between the VC and the investor via an equity contract, represented by the sharing rule $(\alpha, 1-\alpha)$, where $\alpha \in]0;1[$ is kept by the VC.[5] This rule applies both when existing and potential investors are compensated, and it cannot be renegotiated. This assumption is a bit restrictive, but has some empirical support given that on a large scale venture capital funds are structured as limited partnerships, where the VC's (the general partner) compensation is determined based on the investors' (the limited partners) evaluation of the VC's earlier performance. For a given level of reputation it therefore seems reasonable that the compensation scheme is stable over time.[6] Whenever a venture is taken public, the issuing is performed by an independent third party, the *underwriter*, and when we subsequently use the notion clustering, we refer to the underwriter's supply of

[3]See Gompers (1996) and Gompers and Lerner (1999).

[4]This assumption could be eased in order to analyze how much endowed VCs advance in the competition for funding due to their ability to signal project quality.

[5]In practice, VCs are typically payed off via carried interests and fixed management fees, i.e. they get a fixed fraction of the fund's profits and a pre-specified wage in the life span of the fund. Assuming for such a contract instead of the equity contract used in this paper is analogous to interpreting the returns as the individual contributions to the fund's profit, and thus the results of this paper still apply in such a setting. The notation and choice of contract is designed to make the model as simple as possible.

[6]Further, the assumption is not crucial for our computations, but the results are more tractable.

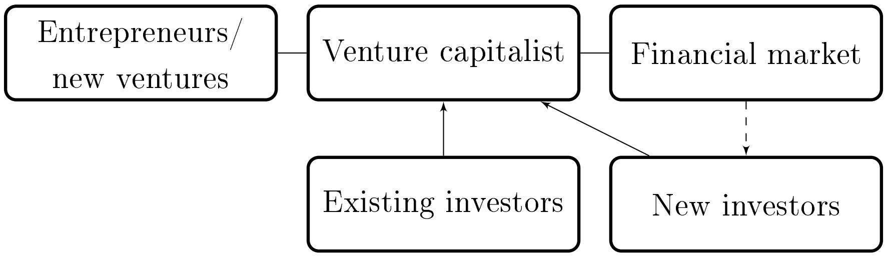

Figure 1: The flow of capital and information. Entrepreneurs provide VCs with potential new ventures. The accumulated capital outlay that new funders are willing to provide (filled arrow) is dependent on the performance of the VC. The performance evaluation is based on information from prior realized returns to existing funders; these returns can be estimated from data from the primary market (dashed arrow).

ventures to be issued. In our monopoly setting this means that clustering stems from the desire to divest a large amount of ventures at a time, and in the monopoly case (1 VC) we are therefore analyzing clustering at the fund level. In our 2-period model, the VC moves first by deciding how many of her existing ventures are to be divested. The ventures are successively divested, such that when she decides whether to divest venture v^n, the returns from earlier divestments, $\{R_i\}_{i=1}^{n-1}$, are publicly known. We assume that the funding decision is based solely on the information from past divestments, and that the VC knows the funding criteria. This means that, in equilibrium, the VC knows whether funding will be provided posterior to each divestment. In other words, if n ventures have been divested, she knows whether funding will be provided if she stops at this point.

Figure 1 shows how information from the financial markets (imperfectly) signals the VC's type. In practice this information is collected in her investment record, but the notion "financial markets" is used to highlight that the adverse selection problem arises because any divestment is risky and that the venture capitalists is induced to divest prematurely without knowing how the primary market evaluates each venture.[7] For notational convenience, we let m_n be the number of successful divestments after n divestments. Divesting early implies a depreciation of realized returns. We assume that returns from existing ventures are identically, indepen-

[7]Ljungqvist et al. (2007) and Gompers et al. (2008) analyze how this exogenous "evaluation" risk affects investment behavior of buyout funds and VC funds.

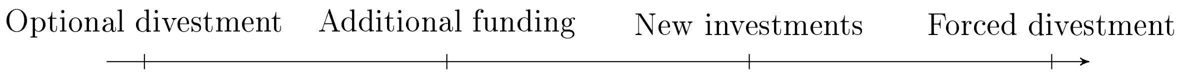

Figure 2: Timeline. The VC divests n ventures, hereby signaling her quality to potential funders. Based on this information, the investor provides the capital outlay, x, which is invested in new ventures. Terminally, all ventures are divested.

dently Bernoulli distributed, such that any venture divested terminally yields a return of

$$R_i^1 = \begin{cases} \bar{R} & \text{with probability } q \\ 0 & \text{with probability } 1-q \end{cases} \qquad \forall i \in \{n+1, \ldots, N\}$$

where $q \in \{q_B, q_G\}$ is the VC's type.[8] Any venture divested early yields

$$R_i^0 = \begin{cases} \bar{R} - \Delta & \text{with probability } q \\ 0 & \text{with probability } 1-q \end{cases} \qquad \forall i \in \{1, \ldots, n\}$$

where $\Delta > 0$ is the depreciation of each venture, if divested early. For simplicity, we assume that the return on the new ventures is gathered in a single return statistic, which is independent of the return from any of the existing ventures not yet divested, and is similarly Bernoulli distributed:

$$R_{new}(x) = \begin{cases} \bar{R}_{new}(x) & \text{with probability } q \\ 0 & \text{with probability } 1-q \end{cases}$$

where $x \in \{0, K\}$. We assume that the funding is crucial for the venture in the sense that $\bar{R}_{new}(x) = \bar{R}_{new} > 0$ if and only if $x = K$, and that new ventures yield a zero return if no funding is provided. The timing of these events is illustrated in Figure 2.

2.2 Strategies

The investor's problem The investor can choose between a risk-free position ($r = 0$) and providing the capital outlay for the new ventures, and assuming

[8]Interchangeably we refer to q as the VC and her type.

(without loss of generality) that his initial endowment equals the needed outlay K, his optimal allocation between the risk-free asset and new ventures is given as $(x-K,x)$ where

$$x = \begin{cases} K & \text{if } K < \mathbb{E}\big[(1-\alpha)R_{new}(K)\big] \\ 0 & \text{otherwise} \end{cases}$$

This result follows directly from the distribution of $R_{new}(x)$. The VC takes this strategy into account when determining her divestment strategy. We assume that

$$q_B(1-\alpha)\bar{R}_{new} < K < q_G(1-\alpha)\bar{R}_{new} \tag{1}$$

such that only a good type would be funded if the investor could observe types. Since q_B would take this into account and mimic q_G as described below, nothing will be revealed about the type of VC, and the investor's funding decision thus relies on a performance evaluation of the divestment path.[9] We assume that the investor's information is given by the triple (n, m_n, N), which means that he knows that n ventures have been divested, m_n turned out successful, and $N-n$ ventures are kept. Based on this information he provides the funding if his conditional expectation of the outcome $(1-\alpha)R_{new}$ is higher than the capital outlay. Assuming that the investor would never provide any funding based on his prior beliefs is equivalent to

$$\big((1-\gamma)q_B + \gamma q_G\big)(1-\alpha)\bar{R}_{new} < K$$

which will be assumed throughout. As already noted, q_B and q_G cannot be separated. The investor takes this into account such that for any given signal (n, m_n, N) he weights the expected return from each type of VC with the conditional probability given the signal. This is simply a Bayesian updating of his prior beliefs $\mathbb{P}\big(q = q_G\big) = \gamma$ and yields the following solution to the decision problem.

[9] The underlying assumption that a good VC cannot signal her true type can be justified in two ways: as already noted the VC is unendowed, and hence cannot compensate the investor in case of a failed IPO by offering a convertible contract that would give a bad VC a negative expected utility. Even if she was endowed and could offer such a convertible, the pooling equilibrium might be more attractive since VCs' typically have several ventures in their portfolio, and paying for every company that fails would probably be too expensive compared to the possible gains. Further, VC's limited liability would in most reasonable scenarios rule out this possibility.

Lemma 1 *$x = K$ if and only if $m_n \geq an + b$ where*

$$a = \log\left[\tfrac{1-q_B}{1-q_G}\right] \Big/ \log\left[\tfrac{q_G}{q_B}\tfrac{1-q_B}{1-q_G}\right] \quad \wedge \quad b = \log\left[\tfrac{1-\gamma}{\gamma}\tfrac{K-q_B(1-\alpha)\bar{R}_{new}}{q_G(1-\alpha)\bar{R}_{new}-K}\right] \Big/ \log\left[\tfrac{q_G}{q_B}\tfrac{1-q_B}{1-q_G}\right]$$

Further, $q_B < a < q_G$ and $b > 0$.

The intersection b increases in K and α and decreases in $\bar{R}_{new}$. This is obvious since a high capital outlay or a high share kept by the VC makes the new venture less valuable to the investor, who therefore would have to be relatively more certain about the VC's quality, thus attempting to decrease the risk of a bad VC hitting the stopping boundary. Similarly, a high prospect, $\bar{R}_{new}$, makes the new venture more valuable, which makes the investor less vulnerable to the risk of funding a bad VC. Further, b is decreasing in the fraction of good VCs, γ, which stems from the fact that the risk of refusing funding to a good VC increases with γ, and a decrease in b compensates for this. Finally, since $b > 0$ is equivalent to the condition $K > (1-\alpha)\bar{R}_{new}((1-\gamma)q_B + \gamma q_G)$ and hence per assumption satisfied, the lemma captures the fact that without any divestments, funding will never be provided. The following example serves as our base case throughout.

Example Assume $q_B = 0.3$ and $q_G = 0.7$, such that $a = 0.5$.[10] Furthermore, $\gamma = 0.1$, $K = 130$, $\alpha = 0.01$, and $\bar{R}_{new} = 300$. In this case, only good VCs hold positive NPV projects since the expected return from a bad VC is $(1-0.01) \cdot 0.3 \cdot 300 = 89.1$, and for a good VC it is $(1-0.01) \cdot 0.7 \cdot 300 = 207.9$, while the capital outlay is 130. Prior to the divestment decision, the investor anticipates a 10% chance of funding a good VC, and hence without any divestments the present value of his share is $0.9 \cdot 89.1 + 0.1 \cdot 207.9 - 130 = -29.02$, and thus without any divestments, no funding will be provided. This result can be confirmed from Lemma 1 by observing that $m_n = 0 < an + b = 0.5 * 0 + 0.92$.

From Figures 3 and 4 we see that a is monotonically increasing in q_B for all q_G, and the curves shift upwards for increasing q_G. b is increasing for low values of q_B and decreasing from some point, $\hat{q}_B(q_G)$. From Figure 4 it is clear that b is decreasing in q_G, and the point $\hat{q}_B(q_G)$ from which b decreases, shifts inwards. The slope of the funding boundary, a, can be interpreted as the average fraction of successful divestments required in order to get funded. Still assuming that bad VCs

[10] It is easy to see that $a = 0.5$ for any $q_B = 1 - q_G$.

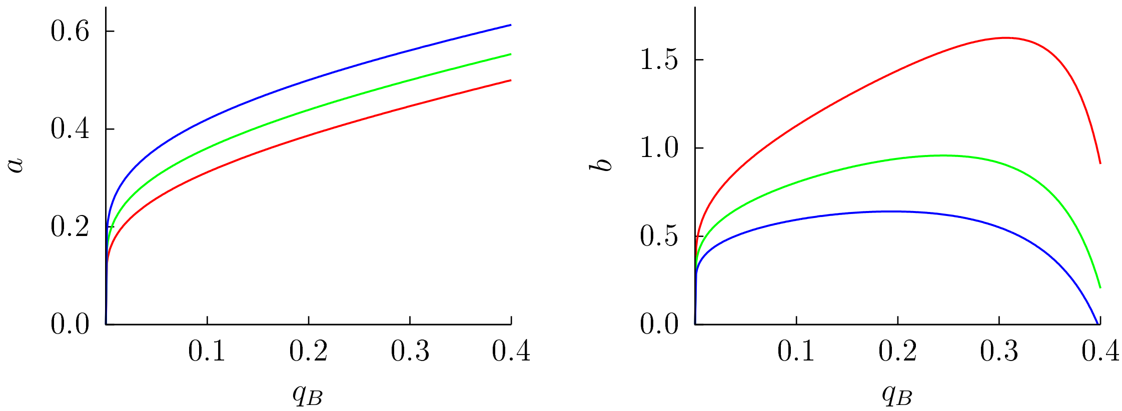

Figure 3: Level curves of a and b for $q_G = 0.6$, 0.7, and 0.8.

hold negative NPV projects, a relatively high q_B makes it harder to distinguish good from bad VCs, and hence the average requirement increases. However, as q_B increases, the expected loss from funding a bad VC decreases, and in the extreme case where the prior expected returns from good VCs can outweigh the expected loss from funding bad ones, the funding boundary initiates (in b) below zero, and hence no early divestments are needed to obtain funding. In Figure 3 this can be seen where b drops below zero. The hump-shape of b illustrates the offsetting effect in the investor's decision problem. A severe funding policy (upward shift in b) decreases the risk of funding a bad VC, but at the same time increases the risk of rejecting a good one. When q_B is low, the investor can choose a less severe policy without substantial risk of bad VCs ever hitting the funding boundary. When q_B increases, this risk increases as well, and the optimal response is to make funding less likely. Up until $\hat{q}_B(q_G)$, the boundary shifts upwards in order to mitigate the risk of funding bad projects, but for $q_B > \hat{q}_B(q_G)$ the expected loss of bad funding decisions is insignificant compared to the risk of rejecting a good VC, and the funding bound shifts downwards. When q_G increases, the intersection decreases, since the expected returns to the investor are increasing, and the risk of rejecting a good VC is sought minimized.

The venture capitalist's problem The VC's optimal strategy takes into account the tradeoff between the additional value of obtaining funding for new ventures and the discount in existing ventures that she must accept in order to divest

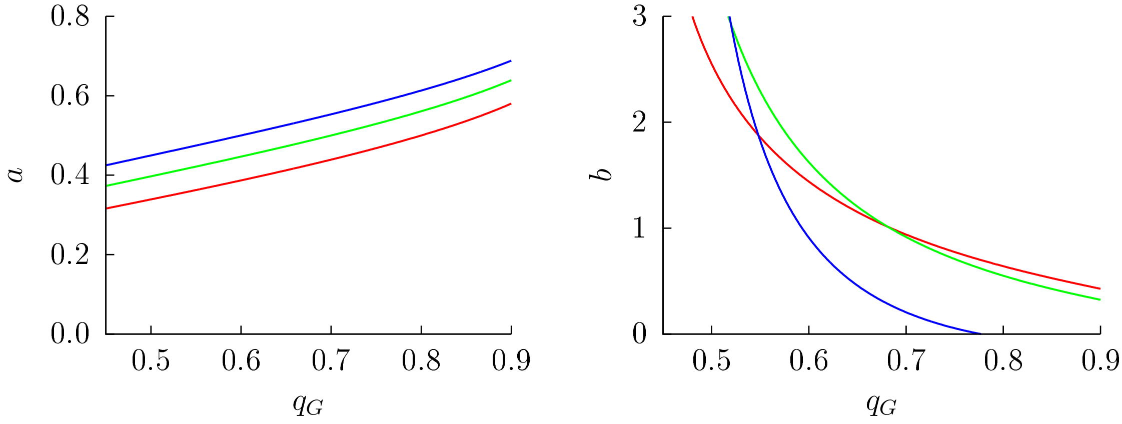

Figure 4: Level curves of a and b for $q_B = 0.2$, 0.3, and 0.4.

prematurely. We will throughout assume that the tradeoff ratio $\bar{R}_{new}/\Delta$ is high, in the sense that she will not stop divesting due to low (strictly positive) funding probabilities. This assumption can be eased, still resulting in a pooling equilibrium; however, in a more general model with a less restrictive assumption on the tradeoff ratio, good and bad VCs might not follow the same divestment paths, hence changing the investor's updating as described previously.[11] Assuming a sufficiently high tradeoff ratio secures a *pooling equilibrium* and is similar to[12]

$$\bar{R}_{new}/\Delta > \lceil aN + b \rceil q_B^{-\lceil aN+b \rceil} \tag{2}$$

From the proof of Lemma 2 it follows that (2) secures a pooling equilibrium. Since the VC is fully informed about the investor's decision problem and its solution, she will for any outcome of the divestment procedure be able to determine whether funding will be provided. Since early divestments suffer a depreciation in returns compared to their true (mature) potential, we would expect that once she is certain to obtain funding, she will stop (premature) divesting. The simplicity of this result stems from our assumption about $\bar{R}_{new}(x)$. A more general relation between raised funding and return potential renders her with a more complex decision problem, which will be explored in Section 3. In this setting, it is evident that if a large number of divestments have failed, the chances of ever getting funded will be very

[11] We would still obtain analytical solutions to the problem, but in much more complicated forms.

[12] The ceil and floor operators $\lceil\cdot\rceil$ and $\lfloor\cdot\rfloor$ are defined for any $x \in \mathbb{R}$ by $\lceil x \rceil = \min\{z \in \mathbb{Z}, z \geq x\}$ and $\lfloor x \rfloor = \max\{z \in \mathbb{Z}, z \leq x\}$.

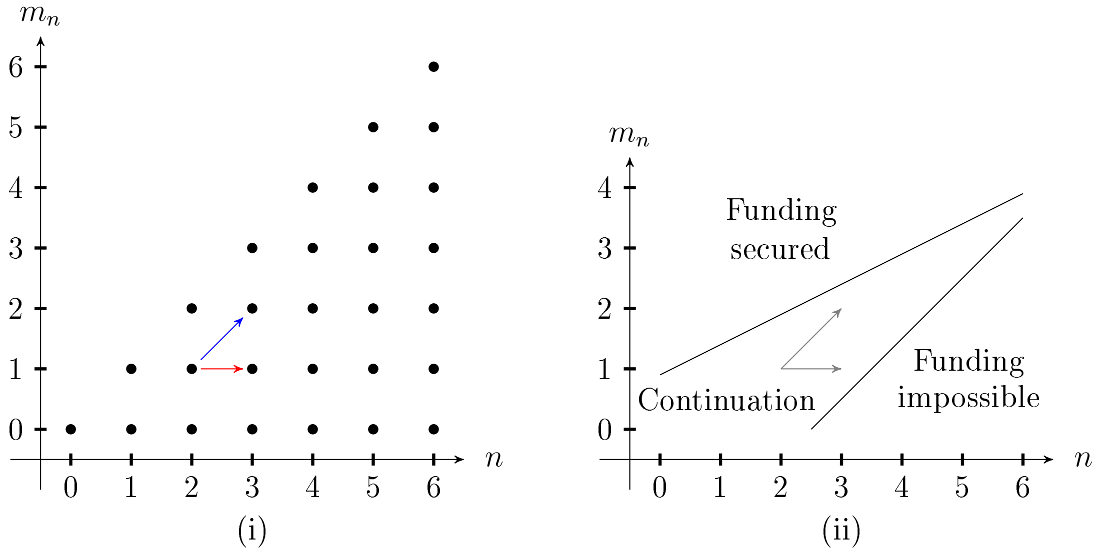

Figure 5: Possible outcomes of the VC's premature divestments (left), and the optimal stopping boundaries given the investor's decision (right).

low, and in extreme cases funding will never be granted. In these cases, there is no reason to divest, due to the depreciation. Henceforth letting n^* denote the optimal number of divestments, we have the following result.

Lemma 2 *If* (2) *is satisfied, the VC's optimal strategy is to divest until either the funding is secured or impossible. Formally, if* $\overline{n} = \min\{n > 0 \,|\, m_n \geq an + b\}$ *and* $\underline{n} = \min\{n > 0 \,|\, m_n < n - \lfloor (1-a)N - b \rfloor\}$ *then the optimal number of divestments is* $n^* = \min\{\overline{n}, \underline{n}\}$.

The decision problem is illustrated in Figure 5, which is based on the example above and on the following extension.

Example Now, assume that the VC holds a portfolio of six ventures, that potentially depreciate with $\Delta = 0.5$ if divested at t_0. In this case, the underlying assumption for Lemma 2 is satisfied since

$$\bar{R}_{new}/\Delta = 600 > 494 = \lceil aN + b \rceil q_B^{-\lceil aN+b \rceil}$$

and she will therefore divest until funding is either secured or impossible as the lemma suggests.

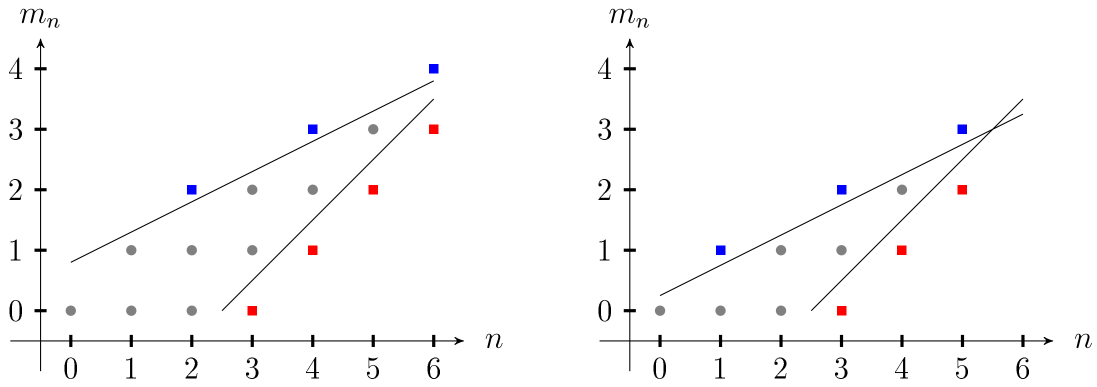

Figure 6: Equilibrium divestment paths and their response to vertical shifts in the funding barrier.

Figure 5 (i) shows the possible outcomes of the divestments; a node (n, m_n) refers to a case where n ventures have been divested, and m_n turned out successful. For instance, at $(2, 1)$, one of two divestments has been successful. Divesting an additional venture means that we move to $(3, 2)$ in case it is successful (blue arrow), and to $(3, 1)$ if it fails (red arrow). Figure 5 (ii) shows the VC's continuation region. We see that all nodes, $(2, 1)$, $(3, 1)$, and $(3, 2)$, are in the continuation region, and Lemma 2 tells us that the VC will keep on divesting until she reaches either the lower bound, in which case she will not get funded, or the upper bound, where funding is secured. Combining the left- and right-hand sides we get a clearer picture of her stopping problem, as well as of the possible outcomes of the sequential divestments (see Figure 6).

2.3 Equilibrium

The funding and divestment strategies outlined above support a unique Bayesian equilibrium. As the VC moves first, she takes the investor's optimal response (from Lemma 1) into account when divesting her portfolio. In this equilibrium, both good and bad VCs can get funding, and both good and bad VCs can be rejected. Later, we will characterize the social loss in this economy, and as is clear by now, the net effect (under- or overinvestment) of adverse selection in the venture industry cannot be determined. However, we will be able to split the aggregate loss into the three relevant inefficiencies: i) loss of potential, due to premature divestment, ii) the risk of rejecting good VCs (underinvestment), and iii) the risk of funding a bad VC (overinvestment). These issues are analyzed in detail in Section 2.7 below. Combining Lemmas 1 and 2, our main result follows.

Theorem 2.1 POOLING EQUILIBRIUM
In the pooling equilibrium, the VC gets funding for new ventures if and only if n ventures are divested and $m_n = \lceil an + b \rceil$ are successful. In case of $m_n < n - \lfloor (1-a)N - b \rfloor$ for some $n \leq N$, n ventures are divested, and she obtains no funding. In equilibrium, her payoffs are $\alpha m_{n^*}(\bar{R} - \Delta)$ at time t_0, and $\alpha\big(\sum_{i=n^*+1}^{N} R_i^1 + R_{new}(x)\big)$ at t_1 where $x \in \{0, K\}$.

The possible equilibrium outcomes in the example above are depicted in Figure 6 (left). The colored nodes are *end nodes.* Blue represents scenarios where funding is obtained, and red nodes denote cases where the VC stops because she knows that funding will never be provided. Consider the node $(2,1)$ again. Since two divestments, where only one turns out successful, do not secure funding, but do not rule it out in case of a successful proceeding path either, this node is in the continuation region. For instance two subsequent successful IPOs will guarantee the funding—at the node $(4,3)$—while two subsequent failed IPO makes funding impossible—at the node $(4,1)$. Note that it will never be optimal for her to keep on divesting once a colored node is reached (and we have to take this into account when calculating the prior probabilities of each divestment path).

As already noted, the slope of the funding barrier is independent by changes in K, α and $\bar{R}_{new}$, while the intersection, b, is increasing in K and α, and decreasing in $\bar{R}_{new}$ because the venture becomes less valuable to the investor if the funding need increases or the VC retains a bigger share for herself, and more valuable if the prospects of successful ventures increase.[13] Figure 6 illustrates how a more valuable project shifts the funding barrier downwards and changes the equilibrium outcomes, such that the VC can stop divesting earlier. As illustrated in the example below, changes in the project specific parameters result in vertical shifts in the funding barrier. The slope is only affected by changes in q_B and q_G. This feature stems from the fact that the investor is trying to solve two problems at once. A low funding barrier reduces the risk of rejecting a good VC, but at the

[13] We will refer to these characteristics as the *quality* of the project/new venture.

same time increases the risk of funding a bad one. Since $q_B < a < q_G$, we would expect that the average fraction of successful divestments from good and bad VCs would tend to a level above and below a, respectively. Thus, a high b mitigates the risk of funding a bad VC, who has just been lucky enough in the early stages to hit the barrier, since the risk of her hitting the barrier later on decreases in n. However, if b is set too high, the risk of rejecting good VCs increases. Since $q_G > a$, a good VC with a large initial portfolio would eventually hit the barrier, but since the portfolio size, N, is ex ante fixed, there is an upper bound on the optimal b. From Figure 3 we see that b is hump-shaped. The intuition is that a low q_B reduces the chance of the funding barrier ever being hit while for high values of q_B the actual expected loss of the funding is decreasing. Figure 4 shows that b is decreasing in q_G, and for very low values of $q_G > q_B$ the expected gain from funding a good VC vanishes; i.e., the right-hand side of (1) tends to K, and funding becomes impossible. But as long as (1) is satisfied, b will be limited. The following example illustrates how vertical shifts in the funding barrier changes the divestment pattern.[14]

Example To see the link between project quality and the divestment behavior, assume that the funding need decreases to $K = 110$. All other parameters stay the same, so the unconditional expected return to the investor is still 100.98, and thus the VC would not get funded without divesting in her existing portfolio. However, since the project quality has increased, she can follow a more lenient divestment strategy. b decreases to 0.39 and a is unchanged. The influence on the equilibrium outcome is illustrated by Figure 6. The lower bound is unchanged since $n - \lfloor (1 - 0.5) \cdot 6 - 0.92 \rfloor = n - \lfloor (1 - 0.5) \cdot 6 - 0.39 \rfloor$.

When the funding barrier is shifted downwards as in Figure 6 (right), the characteristics of the node $(2, 1)$ change. Firstly, the prior probability of reaching it decreases since observing one successful IPO out of two attempts is only possible if the first attempt fails. In this less restrictive case, if the node $(1, 1)$ is reached, funding will be provided and the VC immediately stops divesting. Secondly, having reached $(2, 1)$ increases the chance that she will get her funding at some point,

[14]Figure 6 illustrates how some nodes just above the funding barrier cannot be reached. This will be the case for any parameter choice as shown in Result Impossible Nodes (See the appendix).

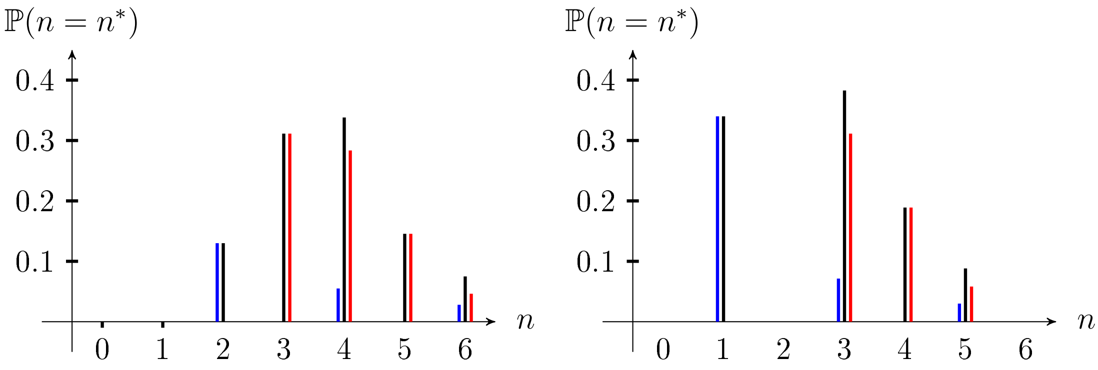

Figure 7: Prior probabilities of each equilibrium outcome: base case (left), downward shift in the funding barrier (right).

relative to the base case. The link between changes in project quality or other parameters in the setting and the equilibrium outcomes is analyzed in greater detail below.

2.4 Distribution of divestments

In addition to the possible outcomes, we can find their probabilities and be a bit more elaborate on the aggregate pattern of divestments. Figure 7 shows the prior probabilities of each equilibrium outcome in the base case (left) and with the lower funding barrier (right). Blue pins indicate the stopping probability where funding is provided, and red pins the cases where no funding is achieved. A black pin adds the probability of the two scenarios for each n^* and shows the overall priors in the course of a divestment round. The aim of this section is to determine how changes in funding policies will change the divestment patterns. In the base case, the funding probability is 21.3% (the probability of hitting a blue node) with an expected number of divestments of 3.7, while in the case with the lower funding barrier the funding probability is 44.1% with 2.7 expected divestments. The fact that the number of divestments tends to decrease when the quality of new ventures increases, or when the private equity market is relatively *bullish* (i.e. γ increases), can have a cyclical effect on the industry. Focusing on the impact of market anticipations, γ, it is apparent that, when the investor's policy is less restrictive and VCs are getting funded based on a relatively small number of divestments, a larger fraction of bad VCs will get funded. Hence, the equilibrium outcome of the divestment game in one period yields a lowering in γ in the next period. Similarly, in a *bearish* environment (i.e. γ decreases), new funders know that prior funding policies have excluded a relatively large group of bad VCs from getting funded, and hence the fraction of good VCs, γ increases. We elaborate on this effect in Section 3 below.

2.5 Competition

This section eases the monopoly assumption of the basic model, and shows how funding limitations in the private equity market encourage more aggressive divestment behavior. Assume that there are two VCs in the industry and denote these A and B. They both hold investment opportunities, yielding a return of $R_{new}(x)$ where x is provided by the investor as before. In the basic setting, the investment opportunity could either be funded in full, or not at all. In this extension each project can be funded halfway, and for simplicity it is assumed that the return is scalable such that $\bar{R}_{new}(\frac{K}{2}) = \frac{1}{2}\bar{R}_{new}(K)$. The funding limitation is such that the investor at the most can invest $\frac{3K}{2}$, which means that the possible outcomes are that i) neither A nor B gets funded, ii) either A or B gets K and the opponent gets $\frac{K}{2}$, or iii) either A or B gets K and the opponent gets 0. In this setting $A \succ B$ means that the investor prefers to fund A in total rather than B, and to ease notation we set $f(n, m_n) = \mathbb{P}_n\big(m_n \geq an + b \wedge A \succ B\big)$, and $h(n, m_n) = \mathbb{P}_n\big(m_n \geq an+b\big)$; i.e. f is the joint probability of A hitting the funding barrier *and* winning the competition against B, and h is the probability of getting funded at all. This setting changes each VC's stopping problem, as described in the following Lemma.[15] We still refer to n^* as the optimal amount of divestments, even though the setting has changed.

Lemma 3 *VC* A *divests at least as much as in the case without competition, and* n^* *is optimal if and only if we in addition have that for all* $n \in \{n^*+1, \ldots, N\}$

$$\bar{R}_{new}/\Delta < \frac{2(n-n^*)}{\mathbb{E}_{n^*}\big[f(n, m_n) + h(n, m_n)\big] - 1} \tag{3}$$

[15]The proof is very similar to the one for Lemma 2, and is available on request.

We can then think of the solution to this optimal stopping problem as the first time the right-hand side increases sufficiently, and we note that, if we fix the RHS at some level, a decrease in the expectation is set off by an increase in n^*. This observation is key to the description of clusterings and grandstanding, and is explained in greater detail below.

IPO clusterings From a statistical perspective we would denote a period with relatively high activity as a clustering period, and we could compare the number of divestments to the prior expectations, and then extract the probability of observing a higher-than-average outcome. However, such an approach does not necessarily describe the reason why a large amount of ventures are divested. To this end, describing a positive correlation between divestment activity across VCs seems more appropriate. In the setting above we could think of VC A receiving information about VC B that made it more likely that A herself would only get $K/2$ in new funding, e.g. information about B having a successful divestment round. This would ceteris paribus decrease the joint probability, f, hence decrease the expectation, and as noted above increase n^*. If information arrives in an alternating fashion, and A has had a successful divestment round, B would respond by divesting in response, and this behavior repeats itself until each VC has reached a sufficiently high benchmark. The intuition from this is clear and shows that VCs' competition for funds can help explain the clustering phenomenon from the supply side of the primary market.

Grandstanding Our model can explain the grandstanding phenomenon in a similar fashion, but without the strategic interactions, and even without the sequential updating of beliefs, as in the clustering case. In practice we observe that young VCs act relatively more aggressively in the course of divesting their portfolios; see Gompers (1996). Since VCs in our model per se are repeated players, their *history* has a great impact on investors' beliefs about them. Assuming that the funding policy punishes bad VCs on a relatively larger scale than good ones, we could reasonably infer that the prior belief of picking a good VC, γ, is increasing, the older the VC is. As already noted, if γ is low, the funding policy is more severe and results in a high funding barrier. This means ceteris paribus that both f and g decrease, implying that the expectation in (3) decreases, and as before n^* increases. This shows that young VCs, in order to compensate for their shorter history, divest more aggressively, both in the basic model and especially when competing for funds with a more experienced VC.[16]

2.6 Empirical predictions

Quantifying the reputation of individual VCs is at least as hard as quantifying their quality. Like with any other rating the determinants of which VCs have the easier access to funding are highly subjective, but in the literature and in practice well established proxies for VCs' reputation include: past performance records, size, and the extend of their network.[17] At this point it is suggested that reputation is measured by one of the following components (or several in combination): years of experience, strength and size of investor network, life earnings and compensation scheme. *Experience* itself is an indirect measure in the sense that if a VC has managed to stay in the industry, she must have been able to successfully raise capital before, and if her ability to support her portfolio companies is under average, this would be revealed over time. If the data is available, an investigation of how the VC's *investor network* has evolved over time might give an even clearer picture of her reputational capital—especially when analyzing the need to gain reputation, as we do here. Her *life earnings* should give us a good picture of how accessible funding will be, and in combination with her *compensation scheme* we should be able to find a good statistic describing her reputation.

VC funding cycles We keep the oligopoly setting and ease the assumption of a single funding round. The investor's prior beliefs about the fraction of good VCs is denoted by γ_t, where $t \in \{0, 1\}$ is the time index. We have already touched upon the cyclical implications of the performance evaluation in the basic model. Low market anticipations in the initial round result in restrictive funding policies via upward shifts in the funding barrier. This policy punishes bad VCs harder than good VCs. Thus the fraction of good VCs increases, and hence the market anticipation in the succeeding round and the funding policy in the next period

[16] Although (3) would have to be adjusted to meet this extension entirely, the intuition seems clear.

[17] Metrick (2007) offers a comprehensive rating of the most influential venture capital companies—worldwide—and a discussion of why they are so successful.

will be less restrictive; we would therefore expect alternating γ-movements. The implications of our model is organized in distinct hypotheses. The first one is motivated by the analysis and the second by the discussion in this section.

Prediction 1 *VCs divest in order to signal high quality and obtain funding for new ventures. High funding levels are triggered by extraordinarily successful IPO proceeds—low funding levels are triggered by relatively many unsuccessful IPOs. The level of competition among VCs increases the amount of IPOs.*

Prediction 2 *Funding policies alternate in the sense that periods with severe limitations in VCs' access to funding are followed by more aggressive divestment behavior. On average, more high quality VCs will succeed and obtain funding in these cases. This causes the investors' beliefs about the fraction of good VCs to increase, resulting in a more lenient funding policy in the following round.*

Grandstanding Our model predicts more aggressive divestment behavior among VCs without reputational capital, i.e. among young VCs. This resembles the findings of Gompers (1996).

Prediction 3 *Among young VCs the average amount of early divestments is high, and we will observe relatively few survivors. Lack of experience does not necessarily create an entry barrier, but lack of reputation does.*

Grandstanding via early divestments means that both the VC, her investors, and the entrepreneurs profit less from the portfolio companies. At the same time if her lack of reputation and the consequential grandstanding is anticipated by potential investors and entrepreneurs, she would be faced with a dual entry barrier in the sense that entrepreneurial offers are not provided on as large scale as to the competitors and raising funding is more costly. This means that young VCs are left with an all-or-nothing chance before being able to act under the same terms as their competitors.

Prediction 4 *Young VCs are—at the industry level—replaced frequently, while more experienced VCs benefit from their easier access to both capital and enterprises. A young VC would posterior to a successful divestment round raise a larger fund and posterior to an unsuccessful round be replaced.*

VC-backed versus non-VC-backed IPOs In our model, obtaining reputational capital is the sole reason for (supply side) clusterings. The results apply to any case where a private equity manager is in control of the divestment decision. Since the most common case by far is related to venture capital, we have restricted our attention to VC-backed IPOs. If we interpret non-VC-backed IPO as any case where the issuer does not care about her reputation, any clustering would stem from informational spill-overs or similar demand side effects.

Prediction 5 *VCs' attempts to gain reputation can account for supply side clusterings. In the course of relatively many successful IPOs, existing non-VC-backed IPOs may occur due to advantageous informational spill-overs.*

2.7 Social loss

In the absence of the adverse selection problem outlined above, a VC would get funded if and only if $q = q_G$, and no ventures would be divested prematurely. That is our benchmark for analyzing the social inefficiency in the venture industry. Any early divestment yields a loss of potential, and in the setup this loss is realized by existing investors and the VC. To keep matters as simple as possible, we have assumed that the change in the potential of each venture is valued (in the primary market) as Δ. This discount is the market's valuation of suboptimal divestment timing and could for instance reflect a higher default risk since the company no longer gains from the presence of a VC. Not only because some good VCs will lose in their effort to get funded, but also because they attempt to signal their true quality/(up-probability) do they deplete the potential of existing ventures. As already noted, we cannot be specific about the net effect on aggregate investment volume. We will only point out that, in equilibrium, both good and bad VCs can be funded, and both good and bad ones can be rejected. Rejecting a good VC yields a loss to the investor since good VCs per se hold positive NPV projects, and the opposite holds true when bad VCs are funded. We will therefore analyze the social loss in terms of the following three inefficiencies separately: i) inefficient divestments, ii) the risk of rejecting q_G, and iii) the risk of funding q_B.

Inefficient divestments Early divested ventures yield a social loss, and we can therefore use the density of divestments as a measure for this inefficiency. Figure

7 shows how the accumulated probabilities shift inwards in a more lenient environment. Note that this distribution does not take into account whether funding is provided or not—only the prior distribution given the shape of the continuation region. With a harsh funding policy, we expect a relatively large fraction of VCs not to get any funding, i.e. they are likely to hit the *lower* bound of their continuation region. Simultaneously, getting funded requires a larger fraction of successes, and hence the chance of hitting the *upper* bound early decreases. Thus, we should expect to see more inefficient divestments in more restrictive environments, and vice versa.

The risk of rejecting a good venture capitalist VCs are highly specialized and seek ventures that could best benefit from their advice and experience. In the context of our model the ability to meet each venture's needs is captured by the success probabilities, $\{q_B, q_G\}$. We can interpret q_B as the case where the VC is not able to support the venture sufficiently and hence should not be funded. In practice, the venture industry is characterized by a small number of well known VCs and a large number of potential VCs. Although the basic model considers a monopoly where the VC does not have to take the divestment strategies of her competitors into account, we have shown in Lemma 3 that competition only gives incentives to divest more. We could think of the signaling problem being more predominant to relatively young VCs. That is, once the investor has identified a VC's ability to support her ventures, the prior beliefs, γ, are updated to a "zero or one" probability for each identified VC. In this case we no longer get the pooling equilibrium from Theorem 2.1, but a case where VCs who have been identified as good get funding, and *outsiders* are left with the signaling problem outlined above. In such a setting, where good VCs are identified and hence are not forced to signal through early divestments, we get closer to the efficient investment level.

In the simple monopoly model, we cannot expect to meet the efficient/first best investment level and allocation. The risk of a good VC not getting funded is

$$\gamma\mathbb{P}\big(n^* = \underline{n} \,|\, q = q_G\big)$$

which is the probability that the VC is good and hits the lower bound before hitting the funding barrier. The relation between γ and the risk of not funding good VCs is non-monotonic. As the investor's prior beliefs increase, the funding barrier shifts downwards, and hence the probability of hitting the lower bound decreases. At the same time, the chance of picking a good VC increases, and hence the risk of not funding one increases as well. This means that if the prior beliefs change, the risk of good VCs not getting funded will increase if the impact on funding policy is sufficiently low, and the risk decreases if the impact is low.

The risk of funding a bad venture capitalist If a bad VC is funded, it only affects the investor himself. Society benefits from new venture-backed companies, since these typically offer some technological advancements. The VC cannot do better than to get funded, so the investor carries the risk of overinvestment. Of course, the risk of misfunding is the sole reason for the adverse selection problem. So, even though it only affects the investor, this risk characterizes a large part of the inefficiency in the venture industry. The risk of misfunding is

$$(1-\gamma)\mathbb{P}\big(n^* = \overline{n} \mid q = q_B\big)$$

and, as before, changes in the prior beliefs affect this risk in two opposite directions. High priors reduce the risk of picking a bad VC in general, while such priors in turn would reduce the funding barrier in order to decrease the risk of rejecting a good one and hence increase the chance of a bad VC getting funded. This means that both risks have non-monotonic relations to the investor's priors.

3 Extensions

This section outlines considerations regarding some of the assumptions of the model. We conclude that including time preferences and risk aversion would only strengthen our results, but at the expense of analytical tractability. Similarly, the assumption of a variable return potential makes the analysis more cumbersome, but enables us to comment on the allocation of effort and capital among several ventures. Alternative contracts are considered, along with perspectives of aggregate performance evaluation. Finally, we comment on the cyclical effects of the divestment behavior and the amount of good and bad VCs in the IPO process. This feature was touched upon in Section 2.4, and in this section ideas for a formal model are presented.

Time preference and risk aversion To keep matters as simple as possible we have assumed that the VC is risk neutral and has a zero time preference. However, the conclusions of the model are unaffected by the introduction of a more reasonable utility. If the VC's utility was modeled by a time-separable VNM utility[18]

$$\mathscr{U}(n, m_n, N) = u\big(m_n\alpha(\bar{R} - \Delta)\big) + \delta\mathbb{E}\big[u\big(\alpha\big[\sum_{i=n+1}^{N} R_i + R_{new}(x)\big]\big)\big]$$

the underlying decision problem would not change from the one already analyzed. The time preference only makes future expected returns less valuable, and hence the tradeoff between depreciation in existing ventures and the prospects of funding is less severe. Unless the time preference is so high as to make the depreciation from early divestments insignificant relative to the discounting, the VC would still divest until her funding is secured, as in Lemma 2.

Regarding risk aversion, keep in mind that the VC has to divest her portfolio no matter what, i.e. the only risk relevant to her is the risk of not getting funded. However, in a more general setting, risk aversion could help to explain why some VCs act more aggressively especially in their divestment strategies. A more wealthy VC would have a relatively lower marginal utility from additional risk taking, and hence it would be interesting to analyze the grandstanding phenomenon in the presence of risk averse VCs. Although making this extension only serves to make the findings from our comments on competitive behavior stronger, it would indeed be helpful to characterize the entrance barrier in terms of both the level of competition and individual characteristics, such as wealth and risk aversion.

Variable return potential The returns from new ventures are captured by a single binomial static. This simplification makes the decision problems solvable by simple *bang-bang controls*, and we can easily identify the equilibrium outcome. The assumption is, however, not very reasonable. In practice, a VC or general partner would have a range of possible ventures to engage in, and each with prospects determined by the *amount* of raised capital. Taking this into account means identifying an aggregated return static, deriving the investor's optimal response

[18] The 1-period utility, u, is increasing and concave.

(aggregated outlay), and including this function in the VC's divestment problem. Hence, the mechanics of the model is unchanged, while the analysis becomes a lot more cumbersome. Introducing variability in the aggregated return links to another interesting problem: the allocation on effort and capital. In general, investors do not have specific control over the choice of ventures and the allocation of effort and capital, so in relation to optimal contracting the VC and the investors are thus left with a moral hazard problem on the VC's side. Some ventures might yield higher private benefits to the VC, although investing in these ventures is inefficient. Incomplete information about her future dispositions and unobservability of her actions render the VC and her investors with a contracting obstacle, and the question of to which extent venture contracts account for these inefficiencies remains open.

Aggregate evaluation of past performance In this section we assume an oligopoly of VCs. In our model, the adverse selection problem stems from investors' choice of VC, and any exogenous uncertainty is captured by the return static R_{new}, and therefore the only information relevant to the investor's decision problem is the type of VC. This simplification ignores a known feature of the venture industry, namely that VCs are highly specialized within sectors, e.g. IT, communication, biotech, etc. We can therefore think of an extended version of the investor's decision problem, where initially a specific sector is chosen, and secondly the VC. In this case, the funding risk is influenced by the performance of all VCs in the sector, and each VC's divestment behavior changes accordingly. If each VC observes the realized returns from *her* sector, the general financial constraint on the sector can be determined, and the optimal divestment strategy would be influenced as described in the following outline. Bad sector performance implies a high general constraint, and each VC is less inclined to try and signal her true type. This because early divestments are costly in terms of loss of potential as explained above. Without any formal modeling we can extend this idea to include our observation about competitive behavior. If the sector performs badly, a good VC would have a strong position competing for funds if these are provided. However, if the market performs *too* badly, even good VCs would stay passive due to the general constraint. On the other hand, if the sector performs comparatively well, the general constraint becomes insignificant, and each VC would only care about her own performance and the competition for funds. Good performance in the sector in general means that a lot of VCs have been successful, and hence the competition for funds is more severe. This means that good sector performance inclines each VC to divest more aggressively since each of them benefits from this, but the effect is restricted by the competition for funds. With a limited aggregated capital outlay and a good sector performance, it becomes harder to obtain an individual share of the outlay that can outweigh the loss of potential of existing ventures. This means that new issues are offered as long as the loss of potential can be outweighed by the prospects from new funding given a *medium* aggregate performance of the sector and relatively high individual evaluation of each VC. A formal model would have to include each VC's response to new IPOs, but that is beyond the scope of this paper.

The above discussion suggests that sector specific IPO clusterings appear when the aggregate performance evaluation is at the median. Too successful environments imply too hard competition for funds, while the opposite implies too high sector constraint.[19] We would therefore expect to see two types of clusterings. Some with relatively many successful divestments, high aggregated outlay, and severe competition for funding, and some with a lot of unsuccessful divestments, followed by a low investment level in the private equity market, and relatively few new ventures being initiated. Although the scope of this model covers divestment *patterns*, this feature supports the well known observation that IPO clusterings on average yield the same return as non-clustered issues.

4 Conclusion

This paper offers a new rationale for IPO clusterings and grandstanding of new VCs. The existing literature on IPOs is supplemented with an analysis of the supply of new venture-backed issues, and our model is kept independent of any demand side dynamics. Hence, we provide a self-contained explanation for the divestment patterns of VCs solely determined by their ability to (partly) signal

[19] This conclusion stems from the assumption that the investor determines the aggregated outlay rationally and does not overreact to either successful or unsuccessful environments. If this was not the case, we would see a self-enforcing aggressive divestment pattern in successful environments, and vice versa in unsuccessful ones.

quality as VCs. The notion of constraining risk is introduced and refers to the fact that VCs' access to new funding is determined by an evaluation of their past performance. We analyze this problem in a simple adverse selection model with one investor and one VC. Necessary conditions for a pooling equilibrium are given and we analyze this equilibrium in detail. The basic setting is extended in order to analyze the influence of competition, and we find that IPO clusterings can be explained by financial constraints in the private equity market. Further, we provide an explanation of the grandstanding phenomenon and conclude that since the investor has lower prior beliefs about young VCs, these are facing a more restrictive funding policy and will therefore act more aggressive both in order to get funding at all and with respect to being among the *winning* VCs. Several other extensions are considered, and we outline a number of interesting directions for future research, especially regarding collective punishment/reward effects within a given sector and an analysis of adverse selection dynamics in the venture industry.

Our model predicts that a more restrictive funding policy will increase the average number of divestments and decrease the overall funding probability as expected. Similar effects are observed for changes in the fraction of high quality VCs. If investors expect a very low fraction of high quality VCs, a very restrictive funding policy is imposed to mitigate the risk of funding a bad VC. This of course punishes good VCs as well, but on average a period with restrictive policies would punish bad VCs relatively harder and hence increase the fraction of good VCs in the next period. We comment on this cyclical effect and outline some considerations regarding its modeling. Further predictions based on the competitive extension of the basic setting are that IPO clusterings are related to funding limitations in the private equity market. We argue that in a setting where VCs take the signaling efforts of their opponents into account, the overall divestment level will increase, and further if each VC receives information about the likelihood of the opponents' success, the divestment level increases even more. This behavior is yet to be investigated empirically, and one of the most important questions to be answered in this regard is how much potential is lost due to these funding limitations. Whenever a venture is divested prematurely, a loss of potential is induced, and this model outlines a number of possible reasons for this loss. Besides the clustering and grandstanding results, there is individual explanatory power in any static that leads to a more restrictive funding policy: lower quality of new ventures, low (expected) fraction of high quality VCs, and a larger spread between good and bad VCs.

We have introduced a new analytical framework to the research on IPOs. Our model focuses on the supply side mechanisms given that the divestment decision is influenced by a repeated player in the private equity market—suitably denoted the VC. The analysis supplements the existing literature on IPOs with a model describing divestment patterns independently of any demand side effect. A next step in this research is to incorporate both sides in order to get a clearer picture of the mechanisms and incentives on both sides of the primary market. Further, to establish the connection to the existing literature on reputational venture capital we should consider the cost of becoming an insider. What carries the separating equilibrium result in the reputational capital models outlined in the introduction is the fact that the VC loses all future benefits of being an informed investor. If the VC could take on an observable and costly action that convinces the primary market that she knows the outcome of the IPO (in a more general setting than in the base model), we should be able to unify the results of the existing literature with the ones of this model. Such an extension would require that the VC was endowed, and would in turn yield a minimum requirement for the endowment (an entry barrier). These matters are subjects for future research in this field.

Proofs

Lemma 1

$x = K$ if and only if

$$\mathbb{E}_n \left[R_{new}(K) \right] \geq \tfrac{K}{1-\alpha}$$

which—since $q \in \{q_B, q_G\}$—is equivalent to

$$\mathbb{P}_n \left(q = q_B \right) q_B \bar{R}_{new} + \mathbb{P}_n \left(q = q_G \right) q_G \bar{R}_{new} \geq \tfrac{K}{1-\alpha}$$

which by simple properties of probabilities is equivalent to

$$\mathbb{P}_n \left(q = q_G \right) \geq \frac{\frac{K}{(1-\alpha)\bar{R}_{new}} - q_B}{q_G - q_B} \triangleq X \in]0;1[\tag{4}$$

where $X \in]0;1[$ follows directly from (1). The conditional probability $\mathbb{P}_n \left(q = q_G \right)$ can be evaluated by Bayes' rule;

$$\mathbb{P}_n \left(q = q_G \right) = \frac{\mathbb{P} \left((n, m_n, N) | q = q_G \right) \mathbb{P} \left(q = q_G \right)}{\mathbb{P} \left((n, m_n, N) \right)}$$

where

$$\mathbb{P} \left((n, m_n, N) \right) = \gamma \mathbb{P} \left((n, m_n, N) | q = q_G \right) + (1-\gamma) \mathbb{P} \left((n, m_n, N) | q = q_B \right)$$

implies that (4) reads

$$\frac{\mathbb{P} \left((n, m_n, N) | q = q_G \right)}{\mathbb{P} \left((n, m_n, N) | q = q_B \right)} \geq \frac{1-\gamma}{\gamma} \frac{X}{1-X} \tag{5}$$

Note that if η is the number of q's possible paths from $(0, 0)$ to (n, m_n) for $q \in \{q_B, q_G\}$, the probability of hitting node (n, m_n) is

$$\mathbb{P} \left((n, m_n, N) \right) = \eta q^{m_n} (1-q)^{n-m_n}$$

Since q_B never differs from q_G's optimality condition, we must have $\eta^B = \eta^G$ and (5) reads

$$\left(\tfrac{q_G}{q_B} \tfrac{1-q_B}{1-q_G} \right)^{m_n} \geq \tfrac{1-\gamma}{\gamma} \tfrac{X}{1-X} \left(\tfrac{1-q_B}{1-q_G} \right)^n$$

and by rearranging and substituting X back into the expression, the result follows.

□

Lemma 2

Since q is risk neutral her expected utility after n divestments is

$$\begin{aligned} g_n &= \sum_{i=1}^{n} \alpha R_i^0 + \mathbb{E}_n\big[\sum_{i=n+1}^{N} \alpha R_i^1 + \alpha R_{new}(x)\big] \\ &= \alpha\big[m_n(\bar{R}-\Delta) + \mathbb{E}_n\big[\sum_{i=n+1}^{N} R_i^1\big] + \mathbb{E}_n\big[R_{new}(x)\big]\big] \\ &= \alpha\big[m_n(\bar{R}-\Delta) + (N-n)q\bar{R} + q\bar{R}_{new}\mathbb{P}_n\big(m_n \geq an+b\big)\big] \end{aligned}$$

where the second and third equalities follow since the returns from existing ventures are independent both mutually and of the returns from new ventures. Similarly, for any $\tilde{n} \in \{n+1,\dots,N\}$ we find that

$$\mathbb{E}_n\big[g_{\tilde{n}}\big] = \alpha\big[\mathbb{E}_n[m_{\tilde{n}}](\bar{R}-\Delta) + (N-\tilde{n})q\bar{R} + q\bar{R}_{new}\mathbb{E}_n\big[\mathbb{P}_{\tilde{n}}\big(m_{\tilde{n}} \geq a\tilde{n}+b\big)\big]\big]$$

Clearly, the VC will optimally divest until $g_n > \mathbb{E}_n\big[g_{\tilde{n}}\big]$ for all $\tilde{n}$, which is equivalent to[20]

$$\Delta(\tilde{n}-n) + \bar{R}_{new}\big(h(n,m_n) - \mathbb{E}_n\big[h(\tilde{n},m_{\tilde{n}})\big]\big) > 0 \tag{6}$$

for all $\tilde{n} > n$.[21] Since $\{m_n \geq an+b\}$ is measurable after n divestments, $h(n,m_n) \in \{0,1\}$. For $h(n,m_n) = 1$, (6) is trivially satisfied since $\Delta > 0$ and $\tilde{n} > n$. If $h(n,m_n) = 0$, (6) is satisfied if and only if $\bar{R}_{new}/\Delta < (\tilde{n}-n)\mathbb{E}_n\big[h(\tilde{n},m_{\tilde{n}})\big]^{-1}$ for all $\tilde{n} > n$, which is equivalent to $\bar{R}_{new}/\Delta < \max_{\tilde{n}>n}\big\{(\tilde{n}-n)\mathbb{E}_n\big[h(\tilde{n},m_{\tilde{n}})\big]^{-1}\big\}$. Note that $(\tilde{n}-n)\mathbb{E}_n\big[h(\tilde{n},m_{\tilde{n}})\big]^{-1}$ is maximized for the longest path, where funding is conditional on a unique sequence of (successful) divestments. Since $an+b$ is increasing in n, the longest path satisfying this is the one ending with funding after N divestments, and where the $N-m_n$ first divestments have failed and the last m_n were successful. This means that $m_n = \lceil aN+b \rceil$, and

$$\max_{\tilde{n}>n}\big\{(\tilde{n}-n)\mathbb{E}_n\big[h(\tilde{n},m_{\tilde{n}})\big]^{-1}\big\} = \lceil aN+b \rceil q^{-\lceil aN+b \rceil}$$

thus (6) is satisfied if and only if

$$\bar{R}_{new}/\Delta < \lceil aN+b \rceil q^{-\lceil aN+b \rceil} \tag{7}$$

[20] Calculations are available on request.

[21] We will use the notation $h(k,m_k) = \mathbb{P}_k\big(m_k \geq ak+b\big)$ for $k \in \{0,\dots,N\}$.

which contradicts (2) for both q_B and q_G since the RHS of (7) decreases in q. We conclude that $n = n^*$ is optimal if $h(n, m_n) = 1$, or $\mathbb{E}_n\big[h(\tilde{n}, m_{\tilde{n}})\big] = 0, \forall \tilde{n} > n$.

□

Technical Result 1 Impossible Nodes
If $\lceil an + b \rceil > \lceil a(n-1) + b \rceil$ *then* n *cannot be optimal.*

Proof:
Assume for contradiction that (n, m_n) is optimal. Then $m_n = \lceil an + b \rceil$, and $(m_n - 1, n - 1)$ has been reached. Since $0 < a < 1$ and $\lceil an + b \rceil > \lceil a(n-1) + b \rceil$ we must have that $\lceil a(n-1) + b \rceil = \lceil an + b \rceil - 1$, but then $(n - 1, m_{n-1})$ must have been optimal since

$$m_{n-1} = m_n - 1 = \lceil an + b \rceil - 1 = \lceil a(n-1) + b \rceil$$

which contradicts that (n, m_n) is optimal due to Lemma 2.

□

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