The Market for Venture Capital: Entry, Competition, and the Survival of Start-Up Companies*

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Abstract

Over the last two decades the number of venture capital (VC) firms actively investing in start-up companies in the US has more than tripled. In this paper we examine (i) the response of incumbent VC firms to increased competitive pressure from less experienced entrants, and (ii) the implications for the funding and survival of start-up companies. We first develop an equilibrium model of the VC market with heterogenous entrepreneurs and VC firms. Each VC firm matches endogenously with an entrepreneur, offering capital in exchange for an equity stake. Our theoretical model predicts that entry of new VC firms has a *ripple effect* throughout the entire market: All start-ups then receive more capital in exchange for less equity (implying higher pre-money valuations), and become more likely to survive. We then test these predictions using VC data from Thomson One, and find strong empirical support.

Keywords: Entrepreneurship, Venture Capital, Entry, Matching, Contracts, Externality, Efficiency.

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1 Introduction

In the last two decades the venture capital (VC) market became an important source for entrepreneurs to receive start-up financing, allowing them to bring their innovative products to market. While 408 VC firms in the US actively invested in new ventures in 1991, a total of $1,585$ VC firms provided start-up financing in 2011, an increase of 288% (Thomson One). The market for venture capital has therefore experienced an unprecedented waive of new VC firms entering this market. In fact, about 42 percent of start-up companies receive (at least partially) early-stage financing from an entrant VC firm in a given market (see Table 1 in Section 6.1).

How does the typical entrant VC firm look like? Naturally it has a substantially lower investment experience than incumbent VC firms: The median entrant in a given market went through only 10 prior rounds of financing (in other markets), while the median incumbent VC firm experienced 80 financing rounds (see Table 2 in Section 6.1). And less experienced VC firms have been shown to invest on average in lower-quality projects (e.g. Sørensen (2007)).

With this in mind one would argue that more experienced incumbent VC firms—which invest on average in higher-quality projects—are immune to competition from less experienced entrants for investment opportunities. Thus, beyond the financing of additional and often low-quality projects, one would expect that entry has no significant effect on the VC market, in particular on the investment decisions of incumbent VC firms. However, in this paper we show the opposite: Market entry forces even the experienced incumbent VC firms to offer their entrepreneurs higher valuations (i.e., more capital in exchange for less equity). This in turn improves the survival rate of *all* VC-backed start-up companies. We also find strong empirical support for the existence of this *ripple effect of entry* in the VC market.

To examine the impact of entry we first develop an equilibrium model which accounts for the salient features of the VC market: (i) heterogeneity among VC firms and entrepreneurs, (ii) endogenous matching, and (iii) binding wealth constraints for entrepreneurs. Specifically in our model the market consists of a collection of VC firms, that are heterogenous in terms of their investment expertise (or management expertise), and a collection of entrepreneurs, that are heterogeneous with respect to the quality (or market potential) of their business ideas. VC firms decide whether to enter the market, and to provide selected entrepreneurs with start-up financing in exchange for an equity stake in their ventures. Each VC-backed entrepreneur then needs to exert private effort which affects the success or failure of his venture.[1]

[1]Thus, our framework exhibits a typical one-sided moral hazard problem with respect to the entrepreneur's effort, while the investment of the VC firm is contractible. For models with double-sided moral hazard in the context of the financing of new ventures, see e.g. Casamatta (2003), Schmidt (2003), Repullo and Suarez (2004), Hellmann (2006), and de Bettignies (2008).

In our equilibrium model VC firms and entrepreneurs match endogenously. Each VC contract must then not only satisfy the usual incentive compatibility constraint associated with the moral hazard problem, but must also ensure that an entrepreneur cannot be better off by contracting with an alternative VC firm. In this sense, VC firms are competing for entrepreneurs with promising business ideas, which—as we will show—plays a key role for the design of optimal VC contracts, and thus the survival of start-up companies.[2]

Our equilibrium model of the VC market allows us to examine how market entry affects (i) equilibrium contracts between VC firms and entrepreneurs, and (ii) the survival of VC-backed start-ups. Considering the contractual relationship between heterogenous VC firms and heterogenous entrepreneurs in a market setting is novel, and yields the following insights:[3] First, entry does not only benefit entrepreneurs who then receive VC financing, but also results in all other VC-backed entrepreneurs in the market to receive more start-up capital. One would expect that VC firms, in exchange for more capital, then demand more equity of the start-ups they invest in. However, we find the opposite: Intensified competition due to entry forces incumbent VC firms to offer their entrepreneurs more capital while accepting lower equity stakes in their ventures. The reason is that entry, in an equilibrium setting, forces VC firms to transfer more surplus to their entrepreneurs, which is a combination between offering more start-up capital and accepting less equity.[4] This has a negative effect on the expected returns of VC firms. Our second main insight is that entry of new VC firms enhances the equilibrium survival rate of all start-up companies. This is because retaining a larger equity share improves effort incentives for entrepreneurs, and thus makes their venture more likely to succeed in equilibrium.

Figure 1 provides a simple illustration of the mechanism behind our key results.[5] There are n_E entrepreneurs in the market, seeking venture capital to finance their start-ups. A lower index indicates a higher idea quality, with entrepreneur 1 having the most lucrative business model in the market (vertical ranking). Moreover, initially there are n_{VC} VC firms in the market actively searching for investment

[2]de Bettignies and Chemla (2008) also consider the effects of competition for business ideas, though in a different setting. In their model, a firm wants to attract managers with high-quality ideas for new ventures.

[3]We are only aware of Dam (2007) who also devised an equilibrium model with ex-ante heterogenous VC firms and entrepreneurs. His model, however, has very different features, and his analysis focuses on different aspects of the matching outcome. He considers a market where VC firms are heterogenous with respect to their monitoring ability, and entrepreneurs are heterogenous with respect to their levels of initial wealth. Dam characterizes the matching equilibrium, which turns out to be negative assortative: Firms with higher monitoring ability match with lower wealth entrepreneurs. In contrast, we use a matching framework to examine, theoretically and empirically, the impact of entry on equilibrium VC contracts and the survival of start-up companies.

[4]Gompers and Lerner (2000) showed that increased venture funds also leads to higher valuations of start-up companies. However, it is important here to note that VC firm entry is not equivalent to increased funds for incumbent VC firms. While the implications are the same (higher valuations), the drivers are substantially different (more intense competition versus more money to invest).

[5]For illustrative purposes we consider, unlike in our equilibrium model, discrete types of entrepreneurs and VC firms.

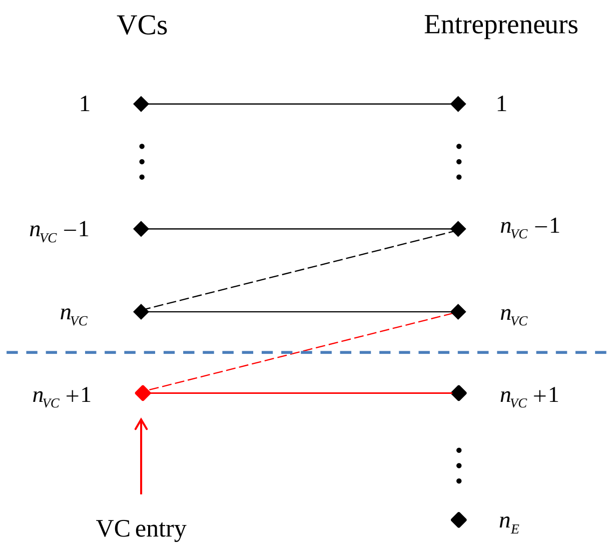

Figure 1: The Ripple Effect of Entry

opportunities, with $n_{VC} < n_E$. A VC firm with a lower index provides more expertise (or value added), with 1 as the most experienced VC firm (vertical ranking). The equilibrium is positive assortative: VC firms of higher quality match with higher quality entrepreneurs, leading to the matching ladder as illustrated in Figure 1 (one-to-one matching).

Consider the entrepreneur with the lowest quality idea, who still gets VC financing (n_{VC}). Without entry his outside option is zero. This in turn allows the corresponding VC firm (n_{VC}) to make him a take-it or leave-it offer, thereby capturing most of the surplus from the new venture.[6] With entry, the new VC firm $n_{VC} + 1$ is also willing to offer a contract to entrepreneur n_{VC}, which improves his outside option. In equilibrium, entrepreneur n_{VC} is still matched with VC firm n_{VC}; however, VC firm n_{VC} must now transfer more surplus to its entrepreneur n_{VC} to account for his improved outside option (through more capital in exchange for less equity). This reduces the expected return for VC firm n_{VC}, so that a match with the next best entrepreneur $n_{VC} - 1$ becomes relatively more attractive, which bids-up entrepreneur $n_{VC} - 1$'s outside option. The higher ranked VC firm $n_{VC} - 1$ is then forced to adjust the contract offer to its entrepreneur ($n_{VC} - 1$) in order to match his improved outside option, and so on. We refer to this mechanism as the *ripple effect of entry* since it impacts all entrepreneur-VC firm pairs in the market.

Our discussion above suggests that entry of less experienced VC firms can cause a ripple effect in the market. In our theoretical model, under certain conditions, the ripple effect travels all the way to the top, so that entry affects all VC-entrepreneur pairs in the market. It then becomes an empirical question

[6]Despite his zero outside option, the entrepreneur still extracts an economic rent in equilibrium due to his zero wealth constraint.

whether the ripple effect of entry gains enough momentum to significantly impact all incumbent VC firms, even the most experienced ones.

We use VC data from Thomson One to test for the ripple effect of entry in the VC market. We find a positive and strong relationship between entry of new VC firms and the pre-money valuations of start-up companies that are financed by incumbent VC firms. This suggests that entry forces incumbent VC firms to offer more surplus to entrepreneurs, either by offering more capital, or asking for less equity, or both. Moreover, our empirical analysis reveals that entry of new VC firms has a positive effect on the survival rate of start-ups receiving funding from incumbent VC firms. Overall this provides empirical support for the existence of the ripple effect of entry, as predicted by our equilibrium model of the VC market.

There is a long-standing tradition in the economics literature to examine the relationship between entry and market efficiency in various market settings. As more firms enter a market, the equilibrium price can either (i) converge to marginal cost (as in Cournot, Bertrand, and Hotelling-type models), (ii) stay constant (as in models of monopolistic competition à la Dixit and Stiglitz (1977)), (iii) converge to a price strictly greater than marginal cost (as in discrete choice models, see e.g. Perloff and Salop (1985)), or even (iv) increase as in models with loyal customers and shoppers, see e.g. Rosenthal (1980). Moreover, free entry does not dissipate profits in models of vertical differentiation due to the 'finiteness property'; see e.g. Shaked and Sutton (1982). In these models high-quality incumbents are therefore shielded from competition from lower-quality entrants. Finally, some oligopoly models predict excessive market entry because of the 'business stealing effect'; see e.g. Mankiw and Whinston (1986).

The VC market, however, does not resemble a typical oligopoly market.[7] Rather, it is characterized by bilateral (and *possibly* interdependent) negotiations between heterogenous agents (VC firms and entrepreneurs). Our equilibrium model therefore facilitates a re-examination of the link between entry and market efficiency. Despite a continuum of VC firms in our model, the market does not converge to the efficient outcome. Moreover, entry into the VC market is *insufficient* from a welfare perspective, even in the absence of any barriers to entry. This is because market entry creates a positive externality for all VC-backed start-ups in the market, which are not internalized by entrants.

Our equilibrium model is closely related to Terviö (2008) who devised an assignment model between heterogenous CEOs and firms to explain the diversity of CEO compensations.[8] The model developed in this paper shares a number of features with Terviö (2008), most notably two-sided matching between a

[7]For example, despite the fact that the VC market is characterized by vertical heterogeneity (in terms of experience of VC firms and idea quality of entrepreneurs), the insights from the Shaked-Sutton vertical differentiation model cannot be readily applied to analyze entry of VC firms. In our equilibrium model we have bilateral bargaining, which leads to endogenous and distinct contracts between the different EN-VC firm pairs.

[8]For other matching models in principal-agent settings, see, e.g., Besley and Ghatak (2005), Serfes (2005, 2008) and Dam and Pérez-Castrillo (2006).

continuum of heterogenous principals and agents. However, our model differs in two key aspects. First, we endogenize the contracts between VC firms and entrepreneurs in a setting with moral hazard. Second, our model features non-transferable utility (NTU), implying that the outside options of entrepreneurs affect equilibrium contracts, and consequently the total surplus from a given relationship. The absence of non-distortionary side-payments is an important characteristic of the VC market due to the limited wealth of entrepreneurs. These key differences to Terviö (2008) generate novel and important insights in how outside options of economic agents as well as entry affect equilibrium contracts and market efficiency.

Our paper is also close in spirit to the equilibrium models of the VC market as devised by Inderst and Müller (2004) and Silviera and Wright (2006). Our paper differs in two important aspects. First, both papers consider a *search* equilibrium, whereas we study *endogenous matching*. The search equilibria in their models are characterized by the ratio of the number of VC firms to the number of entrepreneurs in the market, commonly referred to as "market thickness" in the search theory literature. Using a matching framework, however, we show that it is not just the market thickness that matters; the qualities of entrepreneurial ideas and the investment expertise of VC firms are also critical for the optimal design of VC contracts, especially because these determine the (endogenous) outside options of entrepreneurs. Second, Inderst and Müller (2004) consider homogenous VC firms and entrepreneurs, while Silviera and Wright (2006) introduce ex-post heterogeneity, i.e., the heterogeneity arises after a VC firm is matched with an entrepreneur. In contrast, we explicitly account for different match qualities by allowing entrepreneurs to be ex-ante heterogenous with respect to the market potential of their business ideas, and VC firms with respect to their experience and expertise.[9]

Hochberg et at. (2010) show empirically that syndication among VC firms can be used to deter entry of new firms into a given market. In contrast, we are interested in the effect on incumbents when a new VC firm managed to enter their market. Related to our paper is also Gompers and Lerner (2000), who examine the effect of nationwide capital inflows into the VC market. However, our variable of interest, entry, varies at the local level, while we control for capital inflows.[10]

The remainder of the paper is structured as follows. Section 2 introduces the main features of our equilibrium model of the VC market. Section 3 derives the optimal contract for an isolated entrepreneur-VC firm pair as a benchmark for our analysis. Section 4 then characterizes the matching equilibrium in

[9] Jovanovic and Szentes (2012) develop a theoretical model of the VC market that links the excess return to venture equity to the scarcity of VCs.

[10] Samila and Sorenson (2011) find that increases in the supply of venture capital has a positive effect on firm starts, employment and aggregate income. Their paper is about a positive externality venture capital has on the local economy, while our paper focuses on the positive externality entrants have on start-ups financed by incumbents.

the VC market, and derives the equilibrium contracts between VC firms and entrepreneurs. Section 5 then examines the effect of entry on equilibrium VC contracts and the survival rate of start-up companies. In Section 6 we empirically test our predictions using US data on venture capital investments. Section 7 summarizes our key insights and concludes. All proofs are in the Appendix.

2 The Model

Consider a continuum of risk-neutral entrepreneurs (ENs) and a continuum of risk-neutral venture capital firms (VC firms), each of measure one. ENs are indexed by $i \in E = [0, \overline{E}]$, with $H(i)$ as the distribution of i, and $h(i)$ as its density. VC firms are indexed by $j \in V = [0, \overline{V}]$, with distribution $G(j)$ and density $g(j)$. All entrepreneurs are wealth constrained and their reservation utilities are normalized to zero. There are five dates:

1. ENs conceive business ideas for new ventures.
2. VC firms decide whether to enter the market.
3. Each VC firm matches with an entrepreneur, and offers capital in exchange for an equity stake in the venture.
4. Entrepreneurs exert private effort (moral hazard).
5. All returns are realized.

At date 1, each entrepreneur i conceives an innovative business idea of quality (or market potential) $\mu(i)$, where $\mu(i)$ is increasing and continuously differentiable in i (vertical ranking). To commercially exploit his idea, each entrepreneur requires capital K as well as management expertise, both provided by a VC firm.[11] Let $x(j)$ denote the management expertise of VC firm j, where $x(j)$ is increasing and continuously differentiable in j (vertical ranking). The quality of entrepreneurial ideas ($\mu(i)$) and VC firm expertise ($x(j)$) are common knowledge.[12]

[11]The dependency of entrepreneurs on VC firm expertise excludes debt financing. However, if expertise was not critical, debt financing could be preferred in some cases; see Ueda (2004). To account for debt financing as an alternative to VC financing, once could extend our framework by assuming a strictly positive outside option for entrepreneurs which reflects their expected utility when using debt to start their ventures. As will become clear from our analysis, however, this would not change the quality of our results.

[12]While a potential information asymmetry problem with respect to the qualities of entrepreneurial ideas is not the focus of this paper, one could extend our framework to account for such private information. As is well known from the standard adverse selection literature, entrepreneurs with high quality ideas would then extract an information rent. For matching models with asymmetric information or uncertainty about types, see, e.g., Inderst (2005), Chakraborty, Citanna, and Ostrovsky (2010), and Anderson and Smith (2010).

At date 2, VC firms decide whether to incur the sunk cost $F > 0$ to enter the market. At date 3, each VC firm matches endogenously with one entrepreneur. VC firm j then offers its entrepreneur i capital K_{ij} in exchange for an equity stake $(1 - \lambda_{ij})$, where λ_{ij} denotes the remaining stake for the entrepreneur.[13] The cost of capital faced by each VC firm is exogenous and denoted $r > 0$. To simplify our notation, we henceforth suppress the subscript ij when referring to an arbitrary EN-VC pair. The utility of an entrepreneur who remains unmatched is zero.

At date 4, each entrepreneur exerts private effort e to turn his idea into a marketable product. The non-contractibility of the entrepreneurs effort leads to a typical moral hazard problem.[14] An entrepreneur's private effort determines the likelihood of whether his venture succeeds ($Y = 1$) or fails ($Y = 0$), where $\text{Prob}[Y = 1|e] = e$.[15] The disutility of effort is given by $c(e) = e^2/2$. Finally, at date 5, the profit of each venture is realized and payments are made.

A key property of our framework is the reliance of entrepreneurs on the management expertise of VC firms. Intuitively, the value of this expertise is closely related to the quality of the entrepreneur's specific idea. To capture this notion, let $\Omega \equiv \Omega(\mu, x) > 0$ denote the *match quality* between an entrepreneur with idea quality μ and a VC firm with management expertise x. The match quality Ω is strictly increasing (and continuously differentiable) in μ and x.[16] We assume that ideas and expertise are complements, i.e., $\partial^2\Omega(\mu, x)/(\partial x \partial \mu) > 0$.

Let $\Pi \in \{0, \pi(K, \Omega)\}$ denote the gross profit of a venture, where $\Pi = \pi(K, \Omega) > 0$ if the venture succeeds ($Y = 1$). We assume that $\pi(K, \Omega)$ is increasing and concave in capital K and match quality Ω. We further assume that a higher match quality Ω makes every unit of capital K more productive, i.e., $\partial^2\pi(K, \Omega)/(\partial K \partial \Omega) \geq 0$. Finally, we make the following assumptions to ensure interior solutions:

$$\left.\frac{\partial \pi(K, \Omega)}{\partial K}\right|_{K=0} = \infty \text{ and } \left.\frac{\partial \pi(K, \Omega)}{\partial \Omega}\right|_{\Omega=0} = \infty.$$

[13] To ensure tractability of our equilibrium model, we do not consider separate financing rounds. We thus interpret K_{ij} as the cumulative venture capital invested in a start-up.

[14] In fact, Kaplan and Strömberg (2004) provide empirical evidence that VC investments entail agency conflicts.

[15] To ensure interior solutions, we will assume that the venture's potential profit, denoted by π, is always smaller than one, so that even the first-best effort level e^{fb} guarantees that $\text{Prob}[Y = 1|e^{fb}] < 1$.

[16] In fact, several empirical studies show that prior investment experience (or human capital in general) has a positive effect on the investment performance of VC firms; see e.g. Hsu (2004), Kaplan and Schoar (2005), and Bottazzi, Da Rin, and Hellmann (2008).

3 Benchmark: Optimal VC Contracts in the Absence of Matching

We first derive the optimal contract $\{K, \lambda\}$ for an arbitrary EN-VC firm pair. To do so, we proceed in two steps. First, we characterize the entrepreneur's effort choice for a *given* VC contract. Second, we derive the optimal VC contract when accounting for the entrepreneur's effort.

For a given match quality Ω, VC investment K, and equity share λ, the entrepreneur chooses effort e to maximize his expected utility:

$$\max_{\{e\}} U(e, \lambda, K, \Omega) = \lambda\pi(K, \Omega)e - e^2/2. \tag{1}$$

The entrepreneur's optimal effort is thus given by

$$e^* = \lambda\pi(K, \Omega). \tag{2}$$

To ensure that $\text{Prob}[Y = 1|e^*] = e^* < 1$, we assume that $\pi(K^*, \Omega) < 1$ for the equilibrium investment K^* and any possible match quality Ω.[17] The entrepreneur's participation constraint is always satisfied (assuming an initial outside option of zero) because potential losses (up to K) are entirely incurred by the VC firm.

The VC firm has two instruments to indirectly control the entrepreneur's effort e^*: adjusting the equity share λ and investment K. The optimal combination of λ and K maximizes the VC firm's expected profit as given by

$$\Pi(\lambda, K, e^*, \Omega) = (1 - \lambda)\pi(K, \Omega)e^* - rK. \tag{3}$$

Using e^* as defined by (2), we can write the expected profit of the VC firm as follows:

$$\Pi(\lambda, K, \Omega) = \lambda(1 - \lambda)\pi^2(K, \Omega) - rK. \tag{4}$$

The optimal contract $\{\lambda^*, K^*\}$ serves two objectives: (i) to provide the entrepreneur with sufficient effort incentives to ensure the survival of his venture, and (ii), to generate an adequate return for the VC

[17] Alternatively, one could incorporate a parameter $\zeta > 0$ in the entrepreneur's effort cost function so that $c(e) = \zeta e^2/2$. Assuming a sufficiently high cost parameter ζ would then also ensure that $\text{Prob}[Y = 1|e^*] < 1$.

firm. The next Lemma characterizes the optimal VC contract for an isolated entrepreneur-VC firm pair, which we refer to as *benchmark VC contract*.

Lemma 1 (Benchmark VC Contract) *Consider an arbitrary EN-VC pair in isolation. The optimal VC contract then comprises an equal split of equity, $\lambda^* = 1/2$, and the investment K^* as defined by*

$$\pi(K^*, \Omega) \frac{\partial \pi(K^*, \Omega)}{\partial K} = 2r. \tag{5}$$

When considering an arbitrary EN-VC pair in isolation, it is optimal to equally split the equity of the new venture.[18] We will show in the next section that the split of equity is in general *not* equal when considering the equilibrium of the entire VC market.

We can now derive the expected utility of the entrepreneur using the benchmark VC contract $\{\lambda^*, K^*\}$:

$$U^V(K^*, \Omega) = \pi^2(K^*, \Omega)/8. \tag{6}$$

The superscript V indicates that the entire bargaining power rests with the VC firm (due to the entrepreneur's zero outside option). Thus, $U^V(K^*, \Omega)$ constitutes the lowest possible expected utility level for an entrepreneur in our matching framework, which will play a fundamental role in our analysis of the VC market equilibrium.

Finally, it is straightforward to show that both parties strictly benefit from a superior match quality Ω, rooted either in a more promising business idea (μ) or in a greater VC firm expertise (x). This observation will have important implications for the properties of the matching process in the VC market, which we now turn to.

4 VC Market Equilibrium

We now derive the equilibrium VC contracts in a two-sided market with heterogenous entrepreneurs and VC firms. We proceed in two steps. In Section 4.1, we first identify the general properties of the matching equilibrium in the VC market. We then examine in Section 4.2 the adjustment of VC contracts when considering the equilibrium of the entire VC market.

[18] Note that this result is rooted in our specific effort cost function $c(e) = e^2/2$, and how effort affects the performance of the venture.

4.1 Properties of the Matching Equilibrium

When considering an EN-VC firm pair in isolation, the entrepreneur accepts every contract as long as it is more attractive than his zero outside option. However, if entrepreneurs are free to choose the VC firm with the most attractive offer in a market setting, optimal VC contracts must account for the best alternative available to an entrepreneur. The VC firm thus designs the contract $\{\lambda, K\}$ to maximize its expected profit subject to the entrepreneur receiving at least his outside value u (which we will characterize later). The constrained optimization problem of the VC firm is as follows:

$$\overline{\Pi}(u, \Omega) \equiv \max_{\{\lambda, K\}} (1 - \lambda)\pi(K, \Omega)e^* - rK \tag{7}$$

s.t.

$$\lambda\pi(K, \Omega)e^* - (e^*)^2/2 \geq u, \tag{8}$$

where $e^* = \lambda\pi(K, \Omega)$. The maximized objective function $\overline{\Pi}(u, \Omega)$ defines the *bargaining frontier* between the VC firm and the entrepreneur. Whether the entrepreneur's individual rationality (IR) constraint (8) is binding clearly depends on his reservation utility u. We know that U^V, as defined by (6), constitutes the lower bound of u (when the VC firm holds the entire bargaining power). The maximum value of u, denoted by U^E, constitutes the entrepreneur's expected utility in case he holds the entire bargaining power, with $U^E > U^V$. The next Lemma identifies an important property of the bargaining frontier $\overline{\Pi}(u, \Omega)$.

Lemma 2 (Bargaining Frontier) *The bargaining frontier $\overline{\Pi}(u, \Omega)$ is decreasing in the entrepreneur's reservation utility u for $u \in [U^V, U^E]$.*

We can now define the equilibrium of the VC market when each VC firm matches with one entrepreneur (*one-to-one matching*).[19]

Definition 1 (Matching Equilibrium) *An equilibrium of the VC market consists of a one-to-one matching function $m : E \rightarrow V$ and payoff allocations $\Pi^* : V \rightarrow \mathbb{R}_+$ and $u^* : E \rightarrow \mathbb{R}_+$, that satisfy the following two conditions:*

[19]While often multiple VC firms invest in individual start-up companies (syndication), one VC firm typically takes the lead when negotiating the contract terms with the founder(s); see e.g. Kaplan and Strömberg (2004). We could thus interpret a single VC firm in our model as a syndicate of multiple VC firms with the 'aggregate' expertise x_j.

(i) *Feasibility of* (Π^*, u^*) *with respect to* m*: For all* $i \in E$*,* $\{\Pi^*(m(i)), u^*(i)\}$ *is on the bargaining frontier* $\overline{\Pi}(u, \Omega(\mu(i), x(m(i))))$.

(ii) *Stability of* m *with respect to* $\{\Pi^*, u^*\}$*: There do not exist a pair* $(i, j) \in E \times V$*, where* $m(i) \neq j$*, and outside value* $u > u^*(i)$*, such that* $\overline{\Pi}(u, \Omega(\mu(i), x(j)) > \Pi^*(j)$.

These two conditions guarantee the existence of a stable matching equilibrium in the VC market. The *feasibility* condition requires that the payoffs for VC firms and entrepreneurs are attainable, which is guaranteed whenever the payoffs for any pair $(i, m(i))$ are on the bargaining frontier $\overline{\Pi}(u, \Omega(\mu(i), x(m(i))))$. Moreover, the *stability* condition ensures that all matched VC firms and entrepreneurs cannot become strictly better off by breaking their current partnership, and matching with a new VC firm or entrepreneur.

We can now characterize the matching equilibrium. For simplicity, consider two entrepreneurs i and i' with idea qualities $\mu(i) > \mu(i')$. Suppose that entrepreneur i is matched with VC firm $j = m(i)$, and entrepreneur i' is matched with VC firm $j' = m(i')$. The matching equilibrium is then *positive assortative* (PAM) if the expertise of the VC firms satisfy $x(j) > x(j')$; and *negative assortative* (NAM) if $x(j') > x(j)$. Put differently, we have a positive assortative matching equilibrium (PAM) whenever entrepreneurs with high-quality ideas match with high-expertise VC firms. The opposite occurs with negative assortative matching (NAM). Sørensen (2007) provides empirical evidence that the VC market is positive assortative (PAM): entrepreneurs with high-quality ideas receive start-up financing from more experienced VC firms. It thus remains to verify whether PAM also arises in our equilibrium model.

Applying the criteria derived by Legros and Newman (2007), our matching equilibrium is positive assortative if: (i) the cross-partial derivative of the bargaining frontier $\overline{\Pi}(u, \Omega)$ with respect to the entrepreneur's idea quality μ and the VC firm's management expertise x is positive, i.e., $\partial^2\overline{\Pi}/(\partial\mu\partial x) > 0$; and (ii) it is relatively easier for a high (versus low) expertise VC firm to transfer surplus to an entrepreneur, i.e., $\partial^2\overline{\Pi}/(\partial u\partial x) \geq 0$. The first condition is the standard complementarity condition that guarantees positive assortative matching in models with transferable utility (see Shapley and Shubik (1972) and Becker (1973)). However, as shown by Legros and Newman, this is not a sufficient condition to guarantee PAM whenever utility is non-transferable, as in our framework.[20] We show in the Appendix that both conditions for PAM are satisfied in our equilibrium model of the VC market.

Positive assortative matching (PAM) implies that the matching function $m(i)$ is increasing in i. Note that the measure of ENs must be equal to the measure of VC firms for the one-to-one matching equilib-

[20] In our framework, utility can be transferred through K and λ. These two instruments, however, transfer surplus imperfectly as they also affect the size of the surplus. Due to the zero wealth assumption for entrepreneurs, side payments from entrepreneurs to VC firms are not feasible, which is an important characteristic of VC markets; see also Sørensen (2007) for a discussion.

rium. Thus, it must hold that $H(i) = G(m(i))$ in order to ensure measure consistency. This implies that $m(i) = G^{-1}(H(i))$. Using this consistency condition, we can derive the slope of the matching function $m(i)$:

$$\frac{dm(i)}{di} = G^{-1'}(H(i))\,h(i) = \frac{h(i)}{G'(G^{-1}(H(i)))} = \frac{h(i)}{g(m(i))}. \tag{9}$$

The slope of the matching function $m(i)$ is equal to the ratio of the densities of EN and VC types, $h(i)$ and $g(m(i))$. Given that market entry is costly for VC firms, there will be a cutoff expertise level below which VC firms do not enter the market. We denote this cutoff by $\underline{j}(F) > 0$ as a function of the entry cost $F > 0$. The lowest-quality entrepreneur who still receives VC financing, denoted $\underline{i}$, is thus defined by $m(\underline{i}) = \underline{j}$. We henceforth use the index i when referring to the match between entrepreneur i and VC firm $m(i)$.

4.2 Market Equilibrium and Optimal VC Contracts

We can now characterize the equilibrium contracts $\{\lambda^M(i), K^M(i)\}$ when considering the entire VC market with endogenous matching (indexed by the superscript M) for all $i > \underline{i}(F)$.

Proposition 1 (Equilibrium VC Contracts) *The equilibrium VC contract between entrepreneur i and VC firm $m(i)$, with $i > \underline{i}(F)$, consists of the equity share*

$$\lambda^M(i) = \frac{\sqrt{2u^*(i)}}{\pi(K^M(i), \Omega)}, \tag{10}$$

and the investment $K^M(i)$ as defined by

$$\frac{\partial \pi(K^M(i), \Omega)}{\partial K(i)} = \frac{r}{\sqrt{2u^*(i)}}. \tag{11}$$

The equity share $\lambda^M(i)$ and investment $K^M(i)$ are both increasing in entrepreneur i's outside option $u^*(i)$ (i.e., $d\lambda^M(i)/du^*(i) > 0$ and $dK^M(i)/du^*(i) > 0$).

The equilibrium contract for entrepreneur i, $\{\lambda^M(i), K^M(i)\}$, accounts for his outside option $u^*(i)$. A better outside option $u^*(i)$ forces VC firm $m(i)$ to offer entrepreneur i more capital $K^M(i)$. When considering an entrepreneur-VC firm pair in isolation, one would expect that the provision of more capital must be compensated by a higher equity stake for the VC firm. According to Proposition 1, however, the opposite is true in an equilibrium setting: A better outside option of its entrepreneur forces the VC firm to offer more capital ($K^M(i)$) while accepting a lower equity stake in the firm ($1 - \lambda^M(i)$). This negative relationship between capital provision and equity for the VC firm is rooted in the need for the VC firm to transfer more surplus, which, in an NTU setting, is a combination of more capital and equity for its entrepreneur.

Using (10) from Proposition 1 with (2) yields the equilibrium effort of entrepreneur i with $e^M(i) = \sqrt{2u^*(i)}$. Clearly, a better outside option $u^*(i)$ also results in a higher equilibrium level of effort (because of more capital and equity for the entrepreneur), and thus improves the likelihood of the venture to succeed.

To fully establish the VC market equilibrium, we need to characterize the value of the outside option $u^*(i)$ for all VC-backed entrepreneurs $i > \underline{i}(F)$. Note that the outside option $u^*(i)$ arises endogenously in our framework. Consider VC firm j which is matched with entrepreneur i (i.e., $m(i) = j$). Because the expected profit of a VC firm is increasing in the match quality Ω, all VC firms j', with $j' < j$, would strictly prefer to match with entrepreneur i. However, it is VC firm j that has the highest willingness to pay for entrepreneur i, and thus to transfer the most utility to EN i. By contrast, it is not optimal for VC firm $m(i)$ to make a contract offer to a lower quality entrepreneur $i' < i$ because such a match would result in a lower expected profit. The equilibrium reservation utility $u^*(i)$ of entrepreneur i therefore ensures that no lower-expertise VC firm j', with $j' < j$, finds it profitable to outbid VC firm j. The next Lemma provides a condition that characterizes the equilibrium outside option $u^*(i)$ for all entrepreneurs $i > \underline{i}(F)$.

Lemma 3 *The equilibrium outside option $u^*(i)$ for entrepreneur i, with $i > \underline{i}(F)$, is characterized by the ordinary differential equation*

$$\frac{du^*(i)}{di} = \frac{2u^*(i) \frac{\partial \pi(K^M(u^*(i)),\Omega)}{\partial \Omega} \frac{\partial \Omega}{\partial \mu} \frac{d\mu(i)}{di}}{2\sqrt{2u^*(i)} - \pi(K^M(u^*(i)), \Omega)} > 0, \tag{12}$$

with the initial condition $u^*(\underline{i}(F)) \equiv U^V(\underline{i}(F))$. Both $\underline{i}(F)$ and $u^*(\underline{i}(F))$ are increasing in the entry cost F.

According to the Picard-Lindelöf Theorem, a unique solution $u^*(i)$ to (12) exists.[21] The unique solution $u^*(i)$ must then (implicitly) satisfy

$$u^*(i|F) = U^V(\underline{i}(F)) + \int_{\underline{i}(F)}^{i} \frac{du^*(s)}{ds} ds. \tag{13}$$

Among all entrepreneurs that receive VC financing, the lowest-quality EN $\underline{i}(F)$—who is matched in equilibrium with the zero-profit VC firm $m(\underline{i}(F))$—has the lowest possible utility $U^V(\underline{i}(F))$ and a zero outside option. The outside options of all other VC-backed ENs, $u^*(i|F)$, are increasing in i. The utility of an arbitrary EN i, with $i > \underline{i}$, thereby depends on the quality of all matches below in the ranking. How fast the outside option $u^*(i|F)$ increases in i depends, among other things, on the effect of entrepreneurial ideas on the match quality ($\partial\Omega/\partial\mu$), and on how fast the quality of ideas increases with the rank of the ENs ($d\mu(i)/di$). If, for example, all business ideas had the same quality (i.e., $d\mu(i)/di = 0$), then $du^*(i)/di = 0$, and all ENs would receive the same utility. We can view this case as a benchmark where the specific matching between entrepreneurs and VC firms is irrelevant for the market outcome. If ENs have business ideas of different qualities ($d\mu(i)/di > 0$), then the matching outcome matters for the VC market equilibrium. This is because the presence of diverse business ideas induces competition among VC firms for investment opportunities, which improves the outside options for all entrepreneurs with $i > \underline{i}$. And according to Proposition 1, a better outside option implies more equity and capital for an entrepreneur in equilibrium.

A key insight so far is that equilibrium VC contracts (when considering the VC market as a whole) differ to optimal contracts for isolated EN-VC firm pairs. Our analysis shows that considering the contracting between an entrepreneur and a VC firm in isolation ignores an important determinant of equilibrium contracts: the competition among VC firms for investment opportunities. The next Proposition sheds light on the importance of taking this competition effect into account when analyzing the VC market.

Proposition 2 *The equilibrium contract $\{\lambda^M(i), K^M(i)\}$ between entrepreneur i and VC firm $m(i)$ exhibits more equity and capital for the entrepreneur compared to the benchmark contract $\{\lambda^*(i), K^*(i)\}$,*

[21] We need $du^*(i)/di$ to be Lipschitz continuous in u and continuous in i. Our assumptions ensure that $du^*(i)/di$ is continuous in i, because i enters $du^*(i)/di$ through $\mu(i)$. The term u enters $du^*(i)/di$ (i) linearly in the numerator, (ii) in a square root in the denominator, and (iii), through the profit function $\pi(\cdot)$ (numerator and denominator). If a differentiable function has a derivative that is bounded everywhere by a real number, then the function is Lipschitz continuous. The linear term and the square root term in $du^*(i)/di$ are both Lipschitz continuous, because u is bounded away from zero. However, we need to assume that $\pi(K,\Omega)$ and $\partial\pi(\cdot)/\partial\Omega$ are also Lipschitz continuous with respect to u. In Section 5 we offer a specific example where we calculate the unique solution $u^*(i)$.

i.e., $\lambda^M(i) > \lambda^*(i)$ *and* $K^M(i) > K^*(i)$. *In equilibrium, entrepreneur* i *then exerts more effort, i.e.,* $e^M(i) > e^*(i)$.

Competition among VC firms for investment opportunities improves the outside options of all VC-backed entrepreneurs (except for the one with the lowest quality idea $\mu(\underline{i})$), forcing VC firms to offer their entrepreneurs more equity $\lambda^M(i)$ and start-up capital $K^M(i)$. This enhances entrepreneurs' incentives to exert effort in order to turn their ideas into marketable products, and as a result, improves the survival rate of their ventures.[22]

5 Entry of VC Firms: The Ripple Effect

We now use our framework to examine how entry of new VC firms affects the market equilibrium. We address the following two questions: First, how does entry affect VC investments in new ventures? Second, how does the equilibrium survival rate of start-up companies respond to entry in the VC market?

We can analyze the impact of entry in our equilibrium model by varying the entry cost F. We know from Lemma 3 that a smaller cost of entry F results in more lower-expertise VC firms entering the market. These VC firms match in equilibrium with lower-quality entrepreneurs who then receive capital for their ventures. More entrepreneurs receiving start-up financing is a direct effect of entry in the VC market. The next Proposition identifies an *indirect* effect of entry on the market equilibrium.

Proposition 3 (Entry and Equilibrium Contracts: The Ripple Effect) *Entry of new VC firms, in response to a lower cost of entry* F*, has the following two effects:*

(i) *All entrepreneurs matched with incumbent VC firms then receive more equity and capital (*$d\lambda^M(i)/dF$*,* $dK^M(i)/dF < 0$ *for all* $i > \underline{i}(F)$*)*

(ii) *All start-up companies financed by incumbent VC firms become more likely to survive (*$de^M(i)/dF < 0$ *for all* $i > \underline{i}(F)$*).*

To explain the rationale behind Proposition 3, consider entrepreneur $\underline{i}(F)$ who has the lowest idea quality $\mu(\underline{i}(F))$ among all VC-backed ENs. The reservation utility of entrepreneur $\underline{i}(F)$ is zero because

[22] One can show, however, that the investment and effort levels—and thus the survival rate—remain sub-efficient from a social perspective. The formal proof is available from the authors upon request.

only the lowest-quality VC firm $m(\underline{i}(F))$ finds it optimal to invest in his start-up. Now suppose that the cost of entry decreases to F', with $F' < F$. VC firms with lower expertise levels will then enter the market and match with the lower-quality entrepreneurs $i \in [\underline{i}(F'), \underline{i}(F))$ who would have remained unmatched given the entry cost F (as $d\underline{i}(F)/dF > 0$). The new VC firm $m(\underline{i}(F)-\varepsilon)$, with $\varepsilon \to 0$, is now also willing to offer a contract to entrepreneur $\underline{i}(F)$, which in turn improves his outside option $u^*(\underline{i}(F'))$. Positive assortative matching (PAM) implies that entrepreneur $\underline{i}(F)$ is still matched in equilibrium with VC firm $m(\underline{i}(F))$. However, we know from Proposition 1 that VC firm $m(\underline{i}(F))$ must now offer its entrepreneur $\underline{i}(F)$ more equity and capital in order to account for his improved outside option. This motivates a higher effort level, and thus improves the venture's likelihood of survival. On the other hand, this reduces the overall profitability for VC firm $m(\underline{i}(F))$; it is therefore optimal for VC firm $m(\underline{i}(F))$ to improve its contract offer to the next best entrepreneur $\underline{i}(F) + \varepsilon$, with $\varepsilon \to 0$. The higher-ranked VC firm $m(\underline{i}(F)+\varepsilon)$ is then forced to adjust the contract offer for its entrepreneur $\underline{i}(F)+\varepsilon$ in order to match his improved outside option, and so on.

Entry therefore benefits all entrepreneurs, and not just the ones that receive financing from the new VC firms. On the other hand, the incumbent VC firms (i.e., the VC firms that would have been in the market anyway) are then compelled to transfer more surplus to their entrepreneurs (through more equity and capital). Nonetheless, the presence of more VC firms improves the overall efficiency of the VC market: all entrepreneurs now receive more equity and capital, which in turn improves the survival chance of their start-ups. The key mechanism behind this implication is the interdependence of all contractual relationships through the endogenous outside options of entrepreneurs. In this sense, entry has a *ripple effect* throughout the entire VC market as it affects *all* entrepreneur-(incumbent) VC firm pairs.

The ripple effect of entry has another important implication: A VC firm entering the market exerts a positive externality on all VC-backed ventures, thus improving the efficiency of the entire VC market. However, this positive externality is not internalized. Entry is therefore always insufficient from a social welfare perspective, even in the absence of barriers to entry ($F = 0$).

To illustrate the ripple effect, consider a simple numerical example with $\pi(K, \Omega) = K^{1/3}\Omega^{1/3}$, $\Omega(x, \mu) = \mu x$, $\mu(i) = 2i$, $x(j) = 2j$, and $r = 1/10$. For simplicity we assume that i and j are uniformly distributed on $[0, 0.45]$.[23] The uniform distribution implies a matching function $m(i)$ with slope one. Figure 2 shows the equilibrium outside options $u^*(i|F)$ of all VC-backed entrepreneurs for the entry costs $F = 0.05$ and $F = 0.07$. Since a lower cost F leads to more entry of VC firms, the marginal VC firm $\underline{i}(F)$ differs for the two cost levels, with $\underline{i}(0.05) = 0.34086 < \underline{i}(0.07) = 0.3707$. To illustrate the

[23] The upper bound of the distribution ensures that $e^*(i) = \sqrt{2u^*(i)} < 1$ for all $i \in E$.

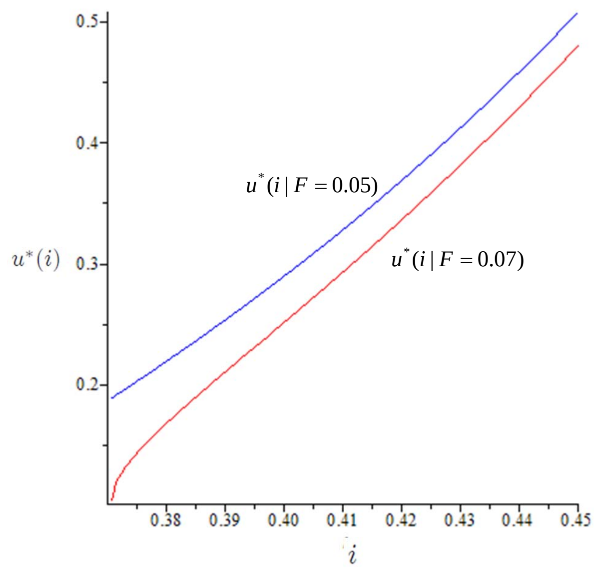

Figure 2: The Ripple Effect of Market Entry – A Numerical Example.

effect of entry on the incumbent VC firms, Figure 2 therefore shows the equilibrium outside options for $i \geq 0.3707$.

Entry intensifies competition among VC firms for investment opportunities. This in turn, as illustrated by Figure 2, improves the outside options of all (incumbent) VC-backed entrepreneurs in the market. The incumbent VC firms are then forced to offer their entrepreneurs more equity and capital, and this improves the survival rate of their start-up companies (since the equilibrium probability of success is positively related to the equilibrium outside options, $e^*(i) = \sqrt{u^*(i)}$).

6 Empirical Evidence

Our equilibrium model of the VC market generates two main predictions: *First*, entry intensifies competition among VC firms for investment opportunities, and thus forces incumbent VC firms to offer more capital and equity for each deal. Put differently, entry has a positive effect on the valuations of start-ups. *Second*, our model predicts a positive relationship between entry of new VC firms in a market and the survival rate of ventures back by incumbent VCs. We now empirically test these predictions.

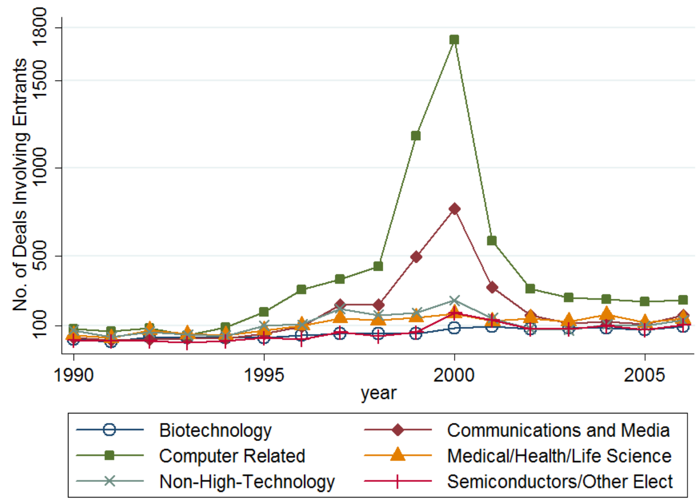

Figure 3: Total Number of Deals Involving Entrants in U.S. (Source: Thomson One)

6.1 Description of Data and Variables

We use the Thomson One database provided by Thomson Financial. This comprehensive database has been extensively used in VC research (see, e.g., Kaplan and Schoar (2005), Sørensen (2007), and Hochberg et al. (2010)). Thomson One provides detailed information on firms that have received venture capital financing. The database includes information on the dates and investment amounts of different financing rounds, the identities of investing VC firms, the development stage and industry groups of portfolio companies, and the dates and types of exits (e.g. IPO, acquisition, or liquidation). Our sample contains all venture capital investments made by U.S. companies from 1990 to 2006, with a total of $20,364$ portfolio companies (or start-ups) and $4,244$ venture capital firms.

It is well known that venture capital firms specialize in specific industries (such as biotechnology or software), and tend to invest in local start-up companies (see, e.g., Hochberg et al. 2010). We therefore define VC markets as follows: First, we differentiate between the six main industry groups in the Thomson One database: "Communications and Media", "Computer Related", "Semiconductors and Other Electronics", "Biotechnology", "Medical, Health and Life Sciences", and "Other". Second, for each industry we group all companies located in the same geographical state.

Following Hochberg et al. (2010), we construct measures of entry for each market. An entrant is defined as a VC firm that invests in a given market for the first time. For each market and year combination, we measure (i) the number of deals entrants are involved in, (ii) the number of deals led by entrants, (iii) the total number of entrants in the market, and (iv) the total number of entrants leading a deal. Following Nahata (2008), a lead investor is defined as the VC firm that participated the earliest

Table 1: Descriptive Statistics I: General

	count	mean	median	max	min	sd
Panel A: Portfolio and VC Characteristics						
survival	29321	.857	1	1	0	.351
year	29321	1999.6	2000	2006	1990	4.47
earlystage	29321	.217	0	1	0	.413
seed	29321	.103	0	1	0	.304
laterstage	29321	.156	0	1	0	.363
expansion	29321	.372	0	1	0	.483
age	29321	4.91	3	1000	0	8.847
cumulative funding amounts	29321	13706	4829	710950	0	26704.9
successful Exit	29321	.534	1	1	0	.499
round number of investors	29321	2.487	2	21	1	1.97
fund size (million $)	29321	254.00	108	6300	.1	493.08
experience of the lead	29321	275.21	153	2444	1	339.18
Panel B: Market Characteristics and Entry Measures						
no. of deals	1369	28.89	12	1244	2	66.42
value-weighted industry avg. B/M ratio	1369	.278	.25535	.794	.081	.11643
no. of deals entrants are involved	1369	12.279	6	504	0	25.215
no. of entrants	1369	14.094	8	427	0	24.354
no. of deals entrants are leading	1369	7.429	4	264	0	13.766
no. of entrants leading deals	1369	6.780	4	226	0	11.81
No. of potential entrants	1369	1533.76	1419	2861	254	811.22

and made the highest investment in the portfolio company. To improve the explanatory power of our regression analysis, we exclude all observations for inactive market periods. This concerns markets with either less than five deals in the current year, or with less than 25 deals in the past five years. This results in a total number of $1,369$ market observations (over the span of seventeen years).

Figure 3 illustrates the number of deals for each industry group where at least one entrant was involved. The different industries have witnessed a similar trend in the entry of new VC firms: Entry peaked in the year 2000, and remained relatively stable after a sharp decline in the years 2001 and 2002. On average, about 40 percent of all deals in a given market involved at least one entrant; see Table 1.

Two key statistics, which have motivated our study, are noteworthy. First, entry is significant. Table 1 shows that, on average, 42.5% of deals in a market (i.e., 12.279 out of 28.89) involve an entrant. Second, entrants have substantially lower experience than incumbents. Table 2 documents that the median entrant experience is 10 prior financing deals (in other markets), while the median experience of incumbents is 80.

We control for the characteristics of (i) markets, (ii) portfolio companies, and (iii) lead investors. The market size is measured by the number of deals in each year. Moreover, on each funding round date, Thomson One identifies a portfolio company as in either one of the following six development stages: "Seed", "Early Stage","Later Stage", "Expansion" and "Other". Based on such information, we

Table 2: Descriptive Statistics II: Number of Prior Financing Rounds of VC Firms since 1975

	count	mean	median	max	min	sd
Incumbent	77240	189.3844	80	2966	1	298.7492
Entrant	41881	53.16439	10	2955	0	132.8459
Total	119121	141.4917	45	2966	0	261.3552
Observations	119121					

construct a set of dummy variables indicating the development stage of a portfolio company at the time of financing round. To control for the unobservable business project qualities of the portfolio companies, we count the cumulative funding amounts received by each portfolio company. We also use the fund size and the investment experience of a VC firm as control variables. In case the fund size information is missing in the data, we use the average of all other funds of the same VC firm. To control for the investment environment for each market, we use the book-to-market ratios for each industry. We obtained these book-to-market ratios as follows: First we identified all VC-backed companies that went public, and determined the most frequently used SIC industry code for each company. Second, for each of the six industry groups from Thomson One, we calculate the value-weighted average book-to-market ratio of all COMPUSTAT companies with the same four-digit SIC codes in year t.

6.2 Entry and Valuation

Our equilibrium model of the VC market predicts a positive relationship between entry and the valuation of portfolio companies financed by incumbent VC firms (which is akin to offering more capital in exchange for less equity). We test for this positive relationship as follows: First, we consider only portfolio companies that are exclusively financed by incumbent VC firms in the year of entry. Second, we only include the financing rounds that took place in the same year of entry. Our regression equation takes the form

$$log(\text{PREVAL})_{imt} = \beta_1 \text{ENTRY}_{mt} + \beta_2 X_{imt} + \beta_3 Y_{jt} + \beta_4 M_{mt} + \phi_m + \tau_t + \epsilon_{imt}, \qquad (14)$$

where $log(\text{PREVAL})_{imt}$ refers to the pre-money value of portfolio company i in market m, which receives a round of financing in year t. Our main variable of interest is ENTRY_{mt}, the market-level entry measure in year t. We control for the characteristics of the VC market through M_{mt}, which includes the market size as well as the industry average book-to-market ratio of public companies. The control variable X_{imt} captures the characteristics of the portfolio companies. This includes (i) the age of a portfolio company, (ii) company development stage dummies (i.e. seed, early stage, later stage, expansion, etc.), (iii) the number of investors in the syndicate, and (iv) the cumulative investment amount received so far by the portfolio company. In addition, we include a dummy variable "successful exit", which indicates whether a portfolio company eventually went public or was acquired (M&A). This allows us to (partly) control for the quality of the business model of a given portfolio company. Moreover, Y_{jt} captures the characteristics of the lead investor, which include the prior investment experience and the fund size of the lead investor. We also include both market fixed effects (ϕ_m), and year fixed effects (τ_t). All the standard errors are clustered at the market level since our measures of entry refers to specific markets.

The regression results are reported in Table 4 (see Appendix). For each specification we find a positive and significant relationship between entry and pre-money valuation. This supports the prediction of our equilibrium model that entry has a ripple effect throughout the VC market: All founders of portfolio companies then benefit from high pre-money valuations, even those who receive financing from incumbent VC firms.

The regression results also suggest that the previous cumulative financing amount is positively related to the valuation of a portfolio company. Start-up companies are therefore more likely to receive a higher valuation at a later development stage. Moreover, an *ex post* successful venture received higher valuations in each financing round. The number of investing VC firms in a given round is significantly and positively associated with the valuation of a start-up company. As the industry average book-to market ratio of the public companies increases, the valuation of a VC-backed start-up in the same industry declines. Furthermore, the valuation increases in the lead investor's experience and investing fund size.

The valuation data from Thomson One are self-reported, and only one-third of the financing rounds in our sample disclose valuations. We note that companies may strategically disclose information about valuations: For instance, a company may choose to not disclose its valuation when the current financing round entails a valuation lower that that of the previous round. To correct for such a selection bias, we follow Hwang, Quigley and Woodward (2005) and perform a Heckman selection correction by estimating an ordered probit model, using the seven potential investment outcomes in each quarter for a VC-backed company. The seven potential outcomes are: (i) shutdown, (ii) acquisition without revelation of value, (iii) no funding at all, (iv) funding without revelation of value, (v) funding with revelation of value, (vi) acquisition with revelation of value, and (vii), IPO. We estimate the probability of each potential outcome for a portfolio company as a function of its development status at the most recent financing round, its industry and geographic location, the stock market capitalization at the time, year effects, the number of days since the most recent financing round, and the type of the previous financing round (i.e., seed, early-stage, later stage, and so on).

We also include the inverse Mill's ratio for each company and financing round from the estimation of the ordered probit model in the specification of (14). The results are shown in Table 5 (see Appendix).

Even after performing the selection-correction we still find that the four different entry measures have a positive and significant effect on a portfolio company's valuation. Compared to the relevant coefficients in Table 4, the selection corrected results indicate only slightly smaller economic effects for three of the four entry measures.

We also run the specification (14) excluding the observations from the year 2000 (the peak of the internet bubble). The results are reported in Table 6. We find that our results still hold when excluding the observations from 2000: Entry continues to have a positive and significant effect on the valuations of start-up companies.

6.3 Entry and the Survival of Start-Up Companies

Our equilibrium model also predicts a positive relationship between entry and the survival probability of portfolio companies backed by incumbent VC firms. To test for this positive relationship we construct a binary variable "survival", which is equal to one whenever one of the following conditions is satisfied: First, the portfolio company received a subsequent round of financing. Second, the company either went public (IPO), or was acquired by another firm (M&A). In all other cases the portfolio company is treated as a write-off, and the binary variable "survival" equals zero.

We then run a linear probability regression to identify the effect of entry on the survival probability of portfolio companies. We only include companies that received capital from incumbent VC firms in the relevant round of financing. The regression equation takes the form

$$Survival_{imt} = \alpha_1 \text{ENTRY}_{mt} + \alpha_2 X_{imt} + \alpha_3 Y_{jt} + \alpha_4 M_{mt} + \phi_m + \tau_t + \epsilon_{imt}. \tag{15}$$

All the covariates are identical to those used in equation (14), except that we now exclude the dummy variable "successful exit". Again, we control for market fixed effects (ϕ_m), and year fixed effects (τ_t).

Table 7 reports the linear estimation results (see Appendix). All results are clustered at the market level. We first performed the estimation using all VC funding rounds between the years 1990 and 2006 (column 2). We then excluded all observations from the year 2000 (the peak of the tech bubble), and repeated our estimation (column 1). With the full sample (column 2), we find that entry has a positive but insignificant effect on survival. However, when excluding the year 2000 (column 1), we find that all four entry measures have a positive and significant effect on the survival probability of portfolio companies.[24]

[24]Nevertheless, when we control for endogeneity of entry (see Section 6.4), all four measures have a positive and significant effect on valuation and survival, with and without the year 2000.

Table 3: Survival Rate of Portfolio Companies and Entry in the VC Market in 2000

	Mean		**p-value**	**No. of Observations***	
	Year 2000	All Other Year		Year 2000	All Other Year
survival	.758	.867	0.000	3193	26488
no. of deals entrants are involved	36	10.569	0.000	94	1277
no. of entrants	41.351	12.079	0.000	94	1277
no. of deals entrants are leading	22.447	6.318	0.000	94	1277
no. of entrants leading a deal	20.234	5.786	0.000	94	1277

* The number of observations for the four entry measures is the number of market-year combinations in the sample since all entry measures are calculated at the market level. The number of observations for the survival variable is the number of financing rounds.

This supports the second prediction of our equilibrium model: Entry has a positive effect on the survival rate of portfolio companies that receive financing from incumbent VC firms.

One may wonder why the year 2000 has a strong impact on our regression results. There are two potential reasons: First, we can see from Table 3 that entry of new VC firms spiked in the year 2000 before the bursting of the tech bubble. However, start-up companies with early-stage financing in 2000 had a significantly lower chance of receiving follow-up financing in later rounds compared to any other year. Nanda and Rhodes-Kropf (2012) find that start-up companies financed in hot markets are on average riskier and more innovative. Entry still leads to higher pre-money valuations (see Table 4 in Section 6.2); however, the experimental nature of start-up companies financed in hot markets, such as in 2000, results in a higher failure rate (see Nanda and Rhodes-Kropf (2012)). Second, after the bursting of the tech bubble in 2000, many VC firms ceased their investment activities, as illustrated by Figure 4. The dramatic decline of available VC funds in the years after 2000 made it very challenging for start-up companies with even high-quality projects to secure follow-up financing. Without later financing rounds, however, many start-up companies did not survive. And our regression results suggest that the negative impact on the survival of start-up companies could not be compensated by entry of new VC firms.

6.4 Omitted Variables

We note that some unobserved market and year effects may lead to more entry in the VC market, while also affecting pre-money valuations and survival rates. One example is the average productivity of portfolio companies within a given market. A positive technology shock would result in higher valuations, and attract VC firms from other markets. We included market and year fixed effects to control for time-

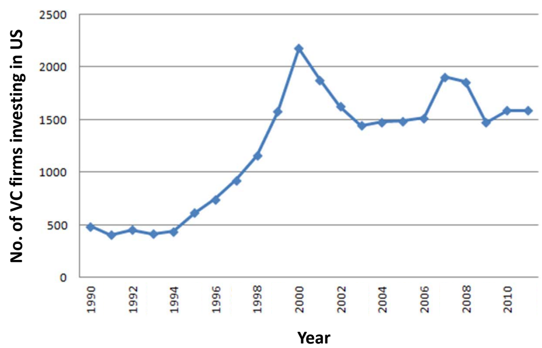

Figure 4: Total Number of VC Firms Investing in the U.S. (Source: Thomson One)

invariant and market-specific variations. However, our regression results could still be biased due to time-varying effects in the different markets. Thus, we need to construct some instrumental variables which correlate with the entry of VC firms, but are independent of unobserved market and year effects.

We use the number of *potential* entrants to control for omitted variables. We define potential entrants as VC firms that have not yet made any investments in a given market, but made investments in other markets over the past three years. In the meantime, we note that the number of potential entrants is invariant to the valuation and survival of each specific portfolio company in a given market.

We then run two-stage-least-squares (2SLS) regressions for both the valuation and survival, where all entry measures are treated as endogenous, and Potential Entrant$_{mt}$ is used to instrument for the entry measures. Table 8 reports our results (see Appendix). All first stage regression results pass the F-test for possible weak instruments. The second stage results show that entry has a positive and significant effect on the pre-money valuations as well as on the survival likelihood.

The coefficients of the 2SLS estimates are larger than the OLS coefficients, which reinforces our theoretical finding that entry has a positive effect on the valuation and survival of start-up companies that receive financing from incumbent VC firms (the ripple effect of entry). The coefficients of all entry measures are significant for the survival analysis (2SLS regressions), when including the year 2000 (column 3), as well as when omitting the year 2000 (column 2). However, the coefficients are larger when excluding the observations from the year 2000 (column 2); this suggests that the effect of entry on survival was less pronounced at the peak of the tech bubble in 2000.

7 Conclusion

What is the role of VC firms when entering new markets? An obvious answer to this question is that entry of new VC firms secures start-up financing for additional, often lower-quality, projects. This paper develops an equilibrium model of the VC market, and identifies another important—and so far overlooked—effect of VC firm entry: It intensifies competition among VC firms for investment opportunities, which results in higher valuations and survival rates of start-up companies financed by the experienced incumbent VC firms. We call this the *ripple effect* of entry. Using VC data from Thomson One we find strong empirical support for the existence of this ripple effect in VC markets.

We considered the market for venture capital as the main application of our equilibrium model with endogenous matching in an NTU setting. Our equilibrium model provides a series of novel and important insights with respect to the interrelationship between the VC market as a whole and the properties of individual VC contracts. However, our insights are much broader and apply in general to markets with vertically differentiated competition, where surplus between any two parties in a contractual relationship cannot be transferred perfectly (NTU). Our model with endogenous matching implies that entry and exit in such vertically differentiated markets affect all contractual relationships, and not just the newly formed (entry) or dissolved (exit) matches. Even when allowing for free market entry, such markets do not converge to the efficient outcome.

Appendix

Proof of Lemma 1

By accounting for the entrepreneur's optimal effort e^* as given by (2), the optimal contract components λ^* and K^* are implicitly characterized by the following two first-order conditions:

$$2\lambda^*(1-\lambda^*)\pi(K^*,\Omega)\frac{\partial \pi(K^*,\Omega)}{\partial K} = r \quad (16)$$

$$(1-2\lambda^*)\pi^2(K^*,\Omega) = 0. \quad (17)$$

Solving (17) for λ^*, and substituting the resulting expression into (16) yields the Lemma. □

Proof of Lemma 2

At the bargaining frontier, the constraint (8) must be binding. Using e^* as defined by (2), the binding constraint can be written as

$$\frac{1}{2}\lambda^2(\pi(K,\Omega))^2 = u.$$

Let λ^M denote the optimal equity share under endogenous matching. Thus, λ^M must satisfy

$$\lambda^M = \frac{\sqrt{2u}}{\pi(K,\Omega)}. \quad (18)$$

Substituting (18) and e^* (as defined by (2)) into (7) yields the unconstrained maximization problem for the VC firm:

$$\max_{\{K\}} \sqrt{2u}\pi(K,\Omega) - 2u - rK.$$

The optimal capital provision under endogenous matching, denoted $K^M(u,\Omega)$, is characterized by the first-order condition:

$$\sqrt{2u}\frac{\partial \pi(K,\Omega)}{\partial K} - r = 0. \quad (19)$$

Next, we can infer from (19) that

$$\frac{dK^M}{du} = -\frac{\frac{\partial \pi(\cdot)}{\partial K}}{2u\frac{\partial^2 \pi(\cdot)}{\partial K^2}} > 0 \text{ and } \frac{dK^M}{d\Omega} = -\frac{\frac{\partial^2 \pi(\cdot)}{\partial K \partial \Omega}}{\frac{\partial^2 \pi(\cdot)}{\partial K^2}} > 0. \quad (20)$$

Thus, the frontier contract $\{\lambda^M, K^M\}$ satisfies

$$\frac{\partial \pi(K^M, \Omega)}{\partial K} = \frac{r}{\sqrt{2u}} \text{ and } \lambda^M = \frac{\sqrt{2u}}{\pi(K^M, \Omega)}. \tag{21}$$

Substituting λ^M, as defined by (18), and e^*, as defined by (2), into (7) yields the bargaining frontier $\overline{\Pi}(\cdot)$:

$$\overline{\Pi}(u, \Omega) = \sqrt{2u}\pi(K^M(u, \Omega), \Omega) - 2u - rK^M(u, \Omega). \tag{22}$$

Differentiating the bargaining frontier $\overline{\Pi}(u, \Omega)$ with respect to u yields

$$\frac{d\overline{\Pi}(\cdot)}{du} = \frac{1}{\sqrt{2u}}\pi(\cdot) + \sqrt{2u}\frac{\partial \pi(\cdot)}{\partial K}\frac{dK^M}{du} - 2 - r\frac{dK^M}{du}, \tag{23}$$

which, by using (19), can be simplified to

$$\frac{d\overline{\Pi}(\cdot)}{du} = \frac{1}{\sqrt{2u}}\pi(\cdot) - 2. \tag{24}$$

Note that $d\overline{\Pi}(\cdot)/du = 0$ at $u = U^V$; see (6). Thus, $d\overline{\Pi}(\cdot)/du < 0$ for all $u > U^V$. Finally, it must hold that

$$\pi(\cdot) \geq -\frac{\left(\frac{\partial \pi(\cdot)}{\partial K}\right)^2}{\frac{\partial^2 \pi(\cdot)}{\partial K^2}} \tag{25}$$

so that $\overline{\Pi}(\cdot)$ is concave for all permissible values of u. □

Positive Assortative Matching Equilibrium (PAM)

We now prove that the two sufficient conditions for PAM, $\partial^2\overline{\Pi}/(\partial\mu\partial x) > 0$ and $\partial^2\overline{\Pi}/(\partial u\partial x) \geq 0$, are satisfied in our equilibrium model of the VC market. First, recall from Proof of Lemma 2 that the VC firm's unconstrained profit function $\overline{\Pi}(\cdot)$ is given by

$$\overline{\Pi}(u, \Omega) = \sqrt{2u}\pi(K^M, \Omega) - 2u - rK^M(u, \Omega).$$

Differentiating $\overline{\Pi}(\cdot)$ with respect to x yields

$$\frac{d\overline{\Pi}(\cdot)}{dx} = \sqrt{2u}\frac{\partial \pi(\cdot)}{\partial K}\frac{dK^M}{d\Omega}\frac{\partial \Omega}{\partial x} + \sqrt{2u}\frac{\partial \pi(\cdot)}{\partial \Omega}\frac{\partial \Omega}{dx} - r\frac{dK^M}{d\Omega}\frac{\partial \Omega}{\partial x}.$$

Using (19), we get the simplified expression

$$\frac{d\overline{\Pi}(\cdot)}{dx} = \sqrt{2u}\frac{\partial \pi(\cdot)}{\partial \Omega}\frac{\partial \Omega}{\partial x}. \tag{26}$$

Differentiating $d\overline{\Pi}(\cdot)/dx$ with respect to μ yields

$$\frac{d^2\overline{\Pi}(\cdot)}{dxd\mu} = \sqrt{2u}\left[\frac{\partial^2 \pi(\cdot)}{\partial \Omega^2}\frac{\partial \Omega}{\partial \mu}\frac{\partial \Omega}{\partial x} + \frac{\partial^2 \pi(\cdot)}{\partial \Omega \partial K}\frac{dK^M}{d\Omega}\frac{\partial \Omega}{\partial \mu}\frac{\partial \Omega}{\partial x} + \frac{\partial \pi(\cdot)}{\partial \Omega}\frac{\partial^2 \Omega}{\partial x \partial \mu}\right]. \tag{27}$$

Using (20), we can rewrite (27) as

$$\frac{d^2\overline{\Pi}(\cdot)}{dxd\mu} = \sqrt{2u}\left[\frac{\partial^2 \pi(\cdot)}{\partial \Omega^2}\frac{\partial \Omega}{\partial x}\frac{\partial \Omega}{\partial \mu} - \frac{\partial^2 \pi(\cdot)}{\partial \Omega \partial K}\frac{\frac{\partial^2 \pi(\cdot)}{\partial K \partial \Omega}}{\frac{\partial^2 \pi(\cdot)}{\partial K^2}}\frac{\partial \Omega}{\partial \mu}\frac{\partial \Omega}{\partial x} + \frac{\partial \pi(\cdot)}{\partial \Omega}\frac{\partial^2 \Omega}{\partial xj \partial \mu}\right]. \tag{28}$$

Since $\partial^2\Omega/\left(\partial x \partial \mu\right) \geq 0$, (28) is positive if

$$\sqrt{2u}\left[\frac{\partial^2 \pi(\cdot)}{\partial \Omega^2} - \frac{\partial^2 \pi(\cdot)}{\partial \Omega \partial K}\frac{\frac{\partial^2 \pi(\cdot)}{\partial K \partial \Omega}}{\frac{\partial^2 \pi(\cdot)}{\partial K^2}}\right]\frac{\partial \Omega}{\partial \mu}\frac{\partial \Omega}{\partial x} > 0. \tag{29}$$

Recall that $\pi(K, \Omega)$ is concave in both of its arguments. This implies that the Hessian determinant must be positive, i.e.,

$$\frac{\partial^2 \pi(\cdot)}{\partial K^2}\frac{\partial^2 \pi(\cdot)}{\partial \Omega^2} - \frac{\partial^2 \pi(\cdot)}{\partial \Omega \partial K}\frac{\partial^2 \pi(\cdot)}{\partial K \partial \Omega} \geq 0. \tag{30}$$

Thus, (29) is positive, which implies that $d^2\overline{\Pi}(\cdot)/(dxd\mu) \geq 0$.

Differentiating $d\overline{\Pi}(\cdot)/dx$ (see (26)) with respect to u yields

$$\frac{d^2\overline{\Pi}(\cdot)}{dxdu} = \frac{1}{\sqrt{2u}}\frac{\partial \pi(\cdot)}{\partial \Omega}\frac{\partial \Omega}{\partial x} + \sqrt{2u}\frac{\partial^2 \pi(\cdot)}{\partial \Omega \partial K}\frac{dK^M}{du}\frac{\partial \Omega}{\partial x}. \tag{31}$$

We show in (20) that $dK^M/du > 0$. Thus, (31) is positive. □

Proof of Proposition 1

The optimal equity share $\lambda^M(i)$ and investment $K^M(i)$ follow directly from the derivations in the Proof of Lemma 2. Moreover, we know from Proof of Lemma 2 that $dK^M/du > 0$. By using (18) and (20) one gets

$$\frac{d\lambda^M}{du} = \frac{\pi(\cdot) + \left(\frac{\partial \pi(\cdot)}{\partial K}\right)^2 / \left(\frac{\partial^2 \pi(\cdot)}{\partial K^2}\right)}{\sqrt{2u}\pi^2(\cdot)}. \tag{32}$$

The concavity condition for the bargaining frontier (25) implies $d\lambda^M/du > 0$. □

Proof of Lemma 3

Consider the match between EN i and VC firm $j = m(i)$. The profit function of VC firm $m(i)$ is given by

$$\overline{\Pi}(i) = \sqrt{2u(i)}\pi(K^M(i), \Omega) - 2u(i) - rK^M(i).$$

Holding $x(j)$ constant and applying the Envelope Theorem, we get

$$\frac{d\overline{\Pi}(i)}{di} = \frac{\pi}{\sqrt{2u(i)}}\frac{du(i)}{di} + \sqrt{2u(i)}\frac{\partial \pi}{\partial \Omega}\frac{\partial \Omega}{\partial \mu}\frac{d\mu(i)}{di} - 2\frac{du(i)}{di}. \tag{33}$$

In the positive assortative matching equilibrium (PAM), it must hold that $d\overline{\Pi}(i)/di = 0$ for all $j \in V$. If $d\overline{\Pi}(i)/di < 0$, the matching equilibrium is not stable because VC firm j would be better off contracting with the marginally lower quality EN $i - \varepsilon$, with $\varepsilon \to 0$. If, on the other hand, $d\overline{\Pi}(i)/di > 0$, then the matching equilibrium is not stable either. EN i would then be better off contracting with the marginally higher expertise VC firm $j + \varepsilon$, with $\varepsilon \to 0$. If a VC firm does not benefit from deviating locally, then it does not benefit from deviating globally.[25] By setting $d\overline{\Pi}(i)/di = 0$ and solving (33) for $du^*(i)/di$, we obtain the ordinary differential equation (ODE) which characterizes $u^*(i)$ for all $i > \underline{i}(F)$:

$$\frac{du^*(i)}{di} = \frac{2u^*(i)\frac{\partial \pi(K^M(u^*(i)),\Omega)}{\partial \Omega}\frac{\partial \Omega}{\partial \mu}\frac{d\mu(i)}{di}}{2\sqrt{2u^*(i)} - \pi(K^M(u^*(i)), \Omega)}. \tag{34}$$

[25] This follows because under PAM the highest willingness to pay among VC firms for an EN belongs to the VC firm which is currently matched with a marginally lower EN.

We can now determine the initial condition for the ODE. To do so, we need to find an index $\underline{i}$ and an associated utility level $u(\underline{i})$ where VC firm $m(\underline{i})$ breaks even. Thus, $\underline{i}$ must satisfy the zero profit condition:

$$\overline{\Pi}(u(\underline{i}),\Omega)=\sqrt{2u(\underline{i})}\pi-2u(\underline{i})-rK^M(\underline{i})-F=0. \tag{35}$$

We now show that such a point exists and is unique. Totally differentiating (35) with respect to i and u yields

$$\frac{du}{di}=-\frac{\sqrt{2u}\frac{\partial\pi}{\partial\Omega}\left(\frac{\partial\Omega}{\partial\mu}\frac{\partial\mu(i)}{\partial i}+\frac{\partial\Omega}{\partial x}\frac{\partial x(j)}{\partial j}\frac{dm(i)}{di}\right)}{\left(\frac{\pi}{\sqrt{2u}}-2\right)}.$$

The sign of du/di depends on the sign of the denominator. Recall that $U^V=\pi^2/8$. It then follows that (i) $du(i)/di<0$ for $u(i)<U^V$, (ii) $du(i)/di=0$ at $u(i)=U^V$ and (iii) $du(i)/di>0$ for $u(i)>U^V$. This implies that the zero-profit function (35) is U-shaped in the (i,u) space with its minimum at $u(i)=U^V=\pi^2/8$. Thus, the initial condition is $u^*(\underline{i}(F))=U^V(\underline{i}(F))$.

Next, we examine how the entry cost F affects $\underline{i}(F)$ and $U^V(\underline{i}(F))$. Totally differentiating (35) with respect to i and F yields

$$\left[\left(\frac{\pi}{\sqrt{2u(i)}}-2\right)\frac{du(i)}{di}+\sqrt{2u(i)}\frac{\partial\pi}{\partial\Omega}\left(\frac{\partial\Omega}{\partial\mu}\frac{\partial\mu(\underline{i})}{\partial i}+\frac{\partial\Omega}{\partial x}\frac{\partial x(j)}{\partial j}\frac{dm(\underline{i})}{di}\right)\right]di-dF=0.$$

Using $u(i)=U^V=\pi^2/8$ we get

$$\frac{d\underline{i}(F)}{dF}=\frac{2}{\pi\frac{\partial\pi}{\partial\Omega}\left(\frac{\partial\Omega}{\partial\mu}\frac{\partial\mu(\underline{i})}{\partial i}+\frac{\partial\Omega}{\partial x}\frac{\partial x(j)}{\partial j}\frac{dm(\underline{i})}{di}\right)}>0. \tag{36}$$

Differentiating U^V with respect to i gives

$$\frac{dU^V}{di}=\frac{\pi}{4}\left[\left(\frac{\partial\pi}{\partial K}\frac{dK^M}{d\Omega}+\frac{\partial\pi}{\partial\Omega}\right)\left(\frac{\partial\Omega}{\partial\mu}\frac{d\mu(\underline{i})}{di}+\frac{\partial\Omega}{\partial x}\frac{dx(\underline{j})}{dj}\frac{dm(\underline{i})}{di}\right)+\frac{\partial\pi}{\partial K}\frac{dK}{du}\frac{dU^V}{di}\right].$$

Using (20) and collecting dU^V/di on the LHS we get

$$\frac{dU^V}{di}=\frac{\frac{\pi}{4}\left[\left(\frac{\partial\pi}{\partial K}\frac{dK^M}{d\Omega}+\frac{\partial\pi}{\partial\Omega}\right)\left(\frac{\partial\Omega}{\partial\mu}\frac{d\mu(\underline{i})}{di}+\frac{\partial\Omega}{\partial x}\frac{dx(\underline{j})}{dj}\frac{dm(\underline{i})}{di}\right)\right]}{\left(1+\frac{\left(\frac{\partial\pi}{\partial K}\right)^2}{\pi\frac{\partial^2\pi}{\partial K^2}}\right)}>0. \tag{37}$$

The sign follows from condition (25); see Proof of Lemma 2. Finally note that $dU^V/di > 0$ and $d\underline{i}(F)/dF > 0$ implies $dU^V(\underline{i}(F))/dF > 0$. □

Proof of Proposition 2

First, (20) implies $K^M(i) > K^*(i)$. Moreover, using (2) and Lemma 1 we get $e^M(i) = \sqrt{2u(i)}$. Thus, $de^M(i)/du(i) > 0$ and $e^M(i) > e^*(i)$. Moreover, we already proved that $d\lambda^M/du > 0$; see Proof of Proposition 1. □

Proof of Proposition 3

Recall that $u^*(i|F)$ is defined by (13), where $u^*(\cdot)$ appears on both sides of (13). For any $i > \underline{i}(F)$, differentiating $u^*(i|F)$ with respect to F yields

$$\frac{du^*(i|F)}{dF} = \left(\frac{dU^V(\underline{i}(F))}{di} - \frac{du^*(\underline{i}(F))}{di}\right)\frac{d\underline{i}(F)}{dF} + \int_{\underline{i}(F)}^{i} \frac{d}{dF}\left(\frac{du^*(s)}{ds}\right) ds. \tag{38}$$

The first term of (38), $dU^V(\underline{i}(F))/di$, is positive and given by (37). The second term, $du^*(\underline{i}(F))/di$, is the differential equation (12) evaluated at the initial condition $i = \underline{i}$, and is positive. Note that $du^*(\underline{i}(F))/di$ dominates $dU^V(\underline{i}(F))/di$ for $i \to \underline{i}$ because the denominator of $du^*(\underline{i}(F))/di$ then goes to infinity. Thus, $\left(dU^V(\underline{i}(F))/di - du^*(\underline{i}(F))/di\right) < 0$. Moreover, $d\underline{i}(F)/dF$ is positive and given by (36).

It remains to examine the term inside the integral. For parsimony, let $\pi \equiv \pi(K^M(u^*(i)), \Omega))$ and $u^* \equiv u^*(i)$. Differentiating (12), we obtain

$$\frac{d}{dF}\left(\frac{du^*(s)}{ds}\right) = \frac{\frac{du^*}{dF}\frac{\partial\Omega}{\partial\mu}\frac{d\mu(i)}{di}\left[2\frac{\partial\pi}{\partial\Omega}\left(\sqrt{2u^*}-\pi\right) + \left(2u^*\frac{\partial^2\pi}{\partial\Omega\partial K}\frac{dK}{du}\right)\left(2\sqrt{2u^*}-\pi\right) + 2u^*\frac{\partial\pi}{\partial K}\frac{\partial\pi}{\partial\Omega}\frac{dK}{du}\right]}{\left(2\sqrt{2u^*}-\pi\right)^2}.$$

Using (20), we get

$$\frac{d}{dF}\left(\frac{du^*(s)}{ds}\right) = \frac{\frac{du^*}{dF}\frac{\partial\Omega}{\partial\mu}\frac{d\mu(i)}{di}\overbrace{\left[2\frac{\partial\pi}{\partial\Omega}\left(\sqrt{2u^*}-\pi\right) - \left(\frac{\frac{\partial^2\pi}{\partial\Omega\partial K}\frac{\partial\pi}{\partial K}}{\frac{\partial^2\pi}{\partial K^2}}\right)\left(2\sqrt{2u^*}-\pi\right) - \frac{\frac{\partial\pi}{\partial\Omega}\left(\frac{\partial\pi}{\partial K}\right)^2}{\frac{\partial^2\pi}{\partial K^2}}\right]}^{\equiv\chi}}{\left(2\sqrt{2u^*}-\pi\right)^2}. \tag{39}$$

When evaluating the term inside the brackets in the numerator of (39) at the initial condition $u^* = \pi^2/8$, we obtain

$$\frac{d}{dF}\left(\frac{du^*(s)}{ds}\right) = \frac{du^*}{dF}\frac{\partial\Omega}{\partial\mu}\frac{d\mu(i)}{di}\frac{\partial\pi}{\partial\Omega}\underbrace{\left(-\pi - \frac{\left(\frac{\partial\pi}{\partial K}\right)^2}{\frac{\partial^2\pi}{\partial K^2}}\right)}_{\equiv\varphi}.$$

The concavity condition for the bargaining frontier, (25), implies $\varphi < 0$.

We can now identify the sign of $du^*(i|F)/dF$. As shown, (38) is negative for $i = \underline{i}$. For i sufficiently close to $\underline{i}$, (39) is also negative, excluding the du^*/dF term. This implies that $du^*(i|F)/dF < 0$ for $i \to \underline{i}$. We can now prove by contradiction that $du^*(i|F)/dF < 0$ must hold for all $i > \underline{i}$. Suppose for a moment that $du^*(i|F)/dF \geq 0$ for some i. Let $(i', m(i'))$ be the first VC-EN pair such that $du^*(i|F)/dF \geq 0$. This implies that all entrepreneurs i with $i < i'$ receive a lower utility in response to a higher fixed cost F. In contrast, VC firm $m(i')$ then transfers more surplus to its entrepreneur i' despite facing less competitive pressure from below. However, this contradicts Lemma 2. Thus, $du^*(i|F)/dF < 0$ for all $i > \underline{i}$. Because $d\lambda^M(i)/du^*(i)$, $dK^M(i)/du^*(i)$, $de^M(i)/du^*(i) > 0$ (see Proposition 1), $du^*(i|F)/dF < 0$ implies $d\lambda^M(i)/dF$, $dK^M(i)/dF$, $de^M(i)/dF < 0$ for all $i > \underline{i}(F)$.
□

Table 4: The Effect of Entry on Pre-Money Valuation

	(1) Log(premoney)	(2) Log(premoney)	(2) Log(premoney)	(2) Log(premoney)
Log(1+no. of deal involving an entrant)	0.307*** (5.31)			
Log(1+no. of entrants)		0.292*** (4.89)		
Log(1+no. of deals led by an entrant)			0.213*** (5.22)	
Log(1+no. of entrant leading deals)				0.195*** (4.55)
Log(leader's experience)	0.0269** (2.20)	0.0268** (2.18)	0.0258** (2.11)	0.0258** (2.11)
Log(leader's fundsize)	0.0776*** (5.09)	0.0779*** (5.06)	0.0779*** (5.10)	0.0779*** (5.09)
Log(age)	0.226*** (7.94)	0.228*** (7.99)	0.225*** (7.80)	0.225*** (7.84)
earlystage	-0.220** (-2.37)	-0.222** (-2.39)	-0.219** (-2.36)	-0.218** (-2.33)
seed	-0.649*** (-6.18)	-0.648*** (-6.15)	-0.646*** (-6.13)	-0.645*** (-6.08)
laterstage	0.302*** (3.77)	0.302*** (3.80)	0.303*** (3.79)	0.305*** (3.83)
expansion	0.112 (1.47)	0.112 (1.47)	0.114 (1.49)	0.115 (1.50)
success	0.271*** (6.37)	0.270*** (6.37)	0.272*** (6.33)	0.271*** (6.32)
Log(cumulative sum received)	0.0941*** (11.27)	0.0941*** (11.19)	0.0941*** (11.27)	0.0941*** (11.21)
Value-weighted industry avg. B/M ratio	-0.665** (-2.12)	-0.628* (-1.95)	-0.625* (-1.89)	-0.682* (-1.97)
Log(round number of investors)	0.386*** (12.60)	0.387*** (12.69)	0.389*** (12.48)	0.389*** (12.59)
Log(no. of deals in market)	-0.0938 (-0.84)	-0.0609 (-0.52)	0.0258 (0.30)	0.0568 (0.59)
Observations	8827	8827	8827	8827
R^2	0.403	0.404	0.402	0.402

t statistics in parentheses (* $p < .1$, ** $p < .05$, *** $p < .01$)

Note: The dependent variable is the log of the pre-money valuation of a portfolio company in that round. ThomsonOne reports the amounts per round and the post-round valuations. We thus derive the pre-money valuation by subtracting the amount per round from the post-round valuation. All models are estimated using OLS, accounting for market fixed effects and year fixed effects. Heteroskedasticity-consistent standard errors (clustered on market-level) are shown in parentheses. Market is defined as the combination of geographic state and industry. Entrants are defined as VC firms which invest in a given market for the first time. Age is the number of years since the portfolio company was founded. Experience of a VC firm is the number of its prior investment rounds. The lead investor is the VC firm that initiated the project and made the highest investment in the portfolio company.

Table 5: The Effect of Entry on Pre-Money Valuation – Selection Corrected

	(1) Log(premoney)	(2) Log(premoney)	(3) Log(premoney)	(4) Log(premoney)
Log(1+no. of deal involving an entrant)	0.307***			
	(5.33)			
Log(1+no. of entrants)		0.293***		
		(4.90)		
Log(1+no. of deals led by an entrant)			0.214***	
			(5.25)	
Log(1+no. of entrant leading deals)				0.196***
				(4.57)
Log(leader's exp)	0.0270**	0.0270**	0.0260**	0.0260**
	(2.19)	(2.17)	(2.09)	(2.10)
Log(leader's fundsize)	0.0770***	0.0773***	0.0773***	0.0774***
	(4.99)	(4.96)	(5.00)	(4.99)
Log(age)	0.226***	0.228***	0.225***	0.225***
	(7.96)	(8.01)	(7.82)	(7.85)
earlystage	-0.221**	-0.223**	-0.220**	-0.220**
	(-2.38)	(-2.40)	(-2.37)	(-2.35)
seed	-0.650***	-0.649***	-0.647***	-0.646***
	(-6.19)	(-6.17)	(-6.14)	(-6.10)
laterstage	0.304***	0.304***	0.305***	0.307***
	(3.80)	(3.83)	(3.83)	(3.86)
expansion	0.110	0.109	0.111	0.112
	(1.44)	(1.45)	(1.47)	(1.48)
success	0.271***	0.270***	0.271***	0.271***
	(6.33)	(6.33)	(6.29)	(6.28)
Log(cumulative sum received)	0.0964***	0.0964***	0.0964***	0.0963***
	(11.82)	(11.74)	(11.85)	(11.78)
Value-weighted industry avg. B/M ratio	-0.672**	-0.635*	-0.632*	-0.689**
	(-2.15)	(-1.97)	(-1.91)	(-1.99)
Log(round number of investors)	0.382***	0.384***	0.385***	0.386***
	(12.29)	(12.39)	(12.19)	(12.30)
Log(no. of deals in market)	-0.0952	-0.0620	0.0246	0.0560
	(-0.85)	(-0.52)	(0.28)	(0.58)
Lambda	0.0318*	0.0316*	0.0316*	0.0308*
	(1.93)	(1.92)	(1.95)	(1.90)
Observations	8827	8827	8827	8827
R^2	0.403	0.404	0.403	0.402

t statistics in parentheses (* $p < .1$, ** $p < .05$, *** $p < .01$)

Note: This table reports the estimation results after correcting for a potential valuation disclosure selection bias, using an ordered probit model following Hwang et al. (2005). Lambda is the inverse Mill's ratio. All models are estimated using OLS, accounting for market fixed effects and year fixed effects. Heteroskedasticity-consistent standard errors (clustered on market-level) are shown in parentheses. Market is defined as the combination of geographic state and industry. Entrants are defined as VC firms which invest in a given market for the first time. Age is the number of years since the portfolio company was founded. Experience of a VC firm is the number of its prior investment rounds. The lead investor is the VC firm that initiated the project and made the highest investment in the portfolio company.

Table 6: The Effect of Entry on Pre-Money Valuation – Excluding the Year 2000

	(1) Log(premoney)	(2) Log(premoney)	(3) Log(premoney)	(4) Log(premoney)
Log(no. of deals involving an entrant)	0.312***			
	(5.46)			
Log(no. of entrants)		0.297***		
		(4.81)		
Log(no. of deals led by an entrant)			0.202***	
			(4.87)	
Log(no. of entrants leading deals)				0.178***
				(4.20)
Log(leader's fundsize)	0.0850***	0.0857***	0.0855***	0.0855***
	(5.06)	(5.09)	(5.10)	(5.12)
Log(leader's experience)	0.0163	0.0161	0.0152	0.0151
	(1.20)	(1.19)	(1.12)	(1.11)
Log(age)	0.236***	0.237***	0.234***	0.234***
	(7.21)	(7.25)	(7.06)	(7.06)
earlystage	-0.439***	-0.440***	-0.439***	-0.441***
	(-4.08)	(-4.07)	(-4.09)	(-4.08)
seed	-0.856***	-0.853***	-0.854***	-0.855***
	(-7.13)	(-7.06)	(-7.15)	(-7.11)
laterstage	0.0777	0.0791	0.0775	0.0785
	(0.79)	(0.81)	(0.79)	(0.80)
expansion	-0.127	-0.127	-0.126	-0.127
	(-1.43)	(-1.42)	(-1.43)	(-1.43)
success	0.311***	0.310***	0.311***	0.311***
	(6.36)	(6.36)	(6.32)	(6.31)
Log(cumulative sum received)	0.0936***	0.0935***	0.0936***	0.0935***
	(9.69)	(9.60)	(9.70)	(9.65)
Value-weighted industry avg. B/M ratio	-0.683*	-0.660*	-0.642	-0.704*
	(-2.15)	(-2.02)	(-1.89)	(-1.98)
Log(round number of investors)	0.333***	0.334***	0.337***	0.337***
	(10.04)	(10.07)	(10.03)	(10.06)
Log(no. of deals in market)	-0.197	-0.168	-0.0636	-0.0289
	(-1.67)	(-1.31)	(-0.69)	(-0.28)
Observations	7548	7548	7548	7548
Adjusted R^2	0.366	0.366	0.364	0.364

t statistics in parentheses (* $p < .1$, ** $p < .05$, *** $p < .01$)

Note: The dependent variable is the log of the pre-money valuation of a portfolio company in that round. ThomsonOne reports the amounts per round and the post-round valuations. We thus derive the pre-money valuation by subtracting the amount per round from the post-round valuation. All models are estimated using OLS, accounting for market fixed effects and year fixed effects. Heteroskedasticity-consistent standard errors (clustered on market-level) are shown in parentheses. Market is defined as the combination of geographic state and industry. Entrants are defined as VC firms which invest in a given market for the first time. The development stage dummies (seed, earlystage, laterstage, expansion) are constructed based on the development information given by ThomsonOne database for portfolio companies at the time of each funding round. Age is the number of years since the portfolio company was founded. Experience of a VC firm is the number of its prior investment rounds. The lead investor is the VC firm that participated the earliest and made the highest investment in the portfolio company.

Table 7: The Effect of Entry on the Probability of Survival

Survival	Excluding Year 2000 (1)	Year 1990 to 2006 (2)
Panel A:		
log(no. of deals involving an entrant)	0.0149**	0.00604
	(2.56)	(0.96)
Market Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Number of observations	27069	30373
R^2	0.044	0.054
Panel B:		
log(no. of entrants)	0.0129**	0.00617
	(2.37)	(1.09)
Market Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Number of observations	27069	30373
Adjusted R^2	0.044	0.054
Panel C:		
log(no. of deals led by an entrant)	0.0124**	0.00653
	(2.39)	(1.16)
Market Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Number of observations	27069	30373
R^2	0.044	0.054
Panel D:		
log(no. of entrants as leader)	0.0112**	0.00522
	(2.28)	(1.03)
Market Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Number of observations	27069	30373
R^2	0.044	0.054

t statistics in parentheses (* $p < .1$, ** $p < .05$, *** $p < .01$)

Note: The independent variable is the financing round. The dependent variable (survival) is binary and equals 1 if the portfolio company went through another financing round at a later stage, went public (IPO), or was acquired (M&A); otherwise the dependent variable is zero. All models are estimated using OLS regressions with market fixed effects and year fixed effects. Control variables include: log of market size, average book-to-market ratio of public companies in the same industry, log of age of portfolio company, company development stage dummies, log of numbers of investors in a financing round, log of experience and total fund size of lead investor, and log of cumulated prior investment amounts. The results are robust to using Probit regressions. Standard errors are clustered at the market level. Column (2) shows the estimation results using all VC funding rounds between the years 1990 and 2006. Column (1) shows the results excluding the year 2000.

Table 8: The Effect of Entry on Pre-money Valuation and Survival – Two-Stage Estimator

	Pre-money valuation		Survival	
	1990 to 2006	Excluding 2000	1990 to 2006	Excluding 2000
Panel A:				
log(no. of deals involving an entrant)	0.304**	0.343**	0.0509**	0.0549***
	(2.39)	(2.53)	(1.98)	(2.91)
R^2	0.396	0.368	0.053	0.043
First Stage Coefficient and First Stage Statistics				
Log(No. of Potential Entrants)	2.579***	2.664***	2.894***	2.887***
	(4.9)	(5.62)	(5.86)	(6.51)
F-Statistic	23.99	31.61	34.3	42.36
Partial R^2	0.1806	0.2027	0.1780	0.1856
Panel B:				
log(no. of entrants)	0.293**	0.331***	0.0487*	0.0523***
	(2.43)	(2.59)	(1.96)	(2.89)
R^2	0.396	0.368	0.052	0.042
First Stage Coefficient and First Stage Statistics				
Log(No. of Potential Entrants)	2.68***	2.764***	3.026***	3.03***
	(5.45)	(6.69)	(6.52)	(7.50)
F-Statistic	29.72	44.79	42.46	56.24
Partial R^2	0.1686	0.1876	0.1620	0.1690
Panel C:				
log(no. of deals led by an entrant)	0.304**	0.349**	0.0465**	0.0509***
	(2.24)	(2.31)	(2.14)	(3.16)
R^2	0.394	0.366	0.052	0.042
First Stage Coefficient and First Stage Statistics				
Log(No. of Potential Entrants)	2.583***	2.623***	3.166***	3.119***
	(4.3)	(4.65)	(6.53)	(6.97)
F-Statistic	18.49	21.64	42.70	48.61
Partial R^2	0.1250	0.1330	0.1433	0.1427
Panel D:				
log(no. of entrants as leader)	0.260**	0.298**	0.0403**	0.0439***
	(2.30)	(2.39)	(2.13)	(3.18)
R^2	0.394	0.365	0.053	0.043
First Stage Coefficient and First Stage Statistics				
Log(No. of Potential Entrants)	3.011***	3.072***	3.65***	3.611***
	(5.16)	(5.67)	(7.23)	(7.75)
F-Statistic	26.6	32.13	52.32	60.03
Partial R^2	0.1654	0.1782	0.1847	0.1865
Number of observations	8827	7347	30373	27068

t statistics in parentheses (* $p < .1$, ** $p < .05$, *** $p < .01$)

Note: The table reports the results of two-stage-least-squares regressions. The sample consists of all the VC deals financed by incumbent VC firms from 1990 to 2006. Column 1 and Column 3 show the estimation results using the full sample. Column 2 and Column 4 show the estimation results after excluding the observations from year 2000. The four entry measures are instrumented with a variable that measures the number of VC firms that have actively invested in the past 3 years, and that have not yet made any prior investments in the market of interest. Both market fixed effects and year fixed effects are included. Standard errors are clustered at the market level.

References

[1] Anderson, Axel, and Lones Smith, 2010, Dynamic Matching and Evolving Reputations, *Review of Economic Studies* 77, 1, 3-29.

[2] Becker, Gary S., 1973, A Theory of Marriage: Part I, *Journal of Political Economy* 81, 813-846.

[3] Besley, Timothy, and Maitreesh Ghatak, 2005, Competition and Incentives with Motivated Agents, *American Economic Review* 95, 616-636.

[4] Bottazzi, Laura, Marco Da Rin, and Thomas Hellmann, 2008, Who are the Active Investors? Evidence from Venture Capital, *Journal of Financial Economics*, 89, 488-512.

[5] Brander, James A., Raphael Amit, and Werner Antweiler, 2003, Venture Capital Syndication: Improved Venture Selection vs. Value Added Hypothesis, *Journal of Economics & Management Strategy*, 11(3), 423-452.

[6] Casamatta, Catherine, 2003, Financing and Advising: Optimal Financial Contracts with Venture Capitalists, *Journal of Finance* 58, 2059-2085.

[7] Chakraborty, Archishman, Alessandro Citanna, and Michael Ostrovsky, 2010, Two-sided Matching with Interdependent Values, *Journal of Economic Theory*, 145(1), 85-105.

[8] Dam, Kaniska, 2007, A Two-sided Matching Model of Monitored Finance, mimeo.

[9] Dam, Kaniska and David Pérez-Castrillo, 2006, The Principal-Agent Matching Market, *Berkeley Electronic Press: Froentiers of Theoretical Economics*, Volume 2, Issue 1, Article 1.

[10] de Bettignies, Jean-Etienne, 2008, Financing the Entrepreneurial Venture, *Management Science*, 54(1), 151-166.

[11] de Bettignies, Jean-Etienne, and Gilles Chemla, 2008, Corporate Venturing, Allocation of Talent, and Competition for Star Managers, *Management Science* 54, 505-521.

[12] Dixit, Avinash, and Joseph Stiglitz, 1977, Monopolistic Competition and Optimum Product Diversity, *American Economic Review* 67, 297-308.

[13] Gompers, Paul, and Josh Lerner, 2000, Money Chasing Deals? The Impact of Fund Inflows on Private Equity Valuations, *Journal of Financial Economics* 55, 281-325.

[14] Hwang, Min, John Quigley, and Susan Woodward, 2005, An Index for Venture Capital, 1987-2003, *Contirubtion to Economic Analysis & Policy* 4(1), 1-43.

[15] Heckman, James, 1979, Sample Selection Bias as a Specification Error, *Econometrica* 47(1), 153-161.

[16] Hellmann, Thomas, 2006, IPOs, Acquisitions, and the Use of Convertible Securities in Venture Capital, *Journal of Financial Economics* 81(3), 649-679.

[17] Hochberg, Yael V., Alexander Ljungqvist, and Yang Lu, 2010, Networking as a Barrier to Entry and the Competitive Supply of Venture Capital, *Journal of Finance* 65, 829-859.

[18] Hsu, David H., 2004, What Do Entrepreneurs Pay for Venture Capital Affiliation?, *Journal of Finance*, 59(4), 1805-1844.

[19] Inderst, Roman, 2005, Matching Markets with Adverse Selection, *Journal of Economic Theory* 121(2), 145-166.

[20] Inderst, Roman, and Holger M. Müller, 2004, The Effect of Capital Market Characteristics on the Value of Start-up Firms, *Journal of Financial Economics* 72, 319-356.

[21] Jovanovic, Boyan, and Bálazs Szentes, 2012, On the Market for Venture Capital, working paper.

[22] Kaplan, Steven N., and Antoinette Schoar, 2005, Private Equity Performance: Returns, Persistence, and Capital Flows, *Journal of Finance*, 60(4), 1791-1823.

[23] Kaplan, Steven N., and Per Strömberg, 2003, Financial Contracting Theory Meets the Real World: An Empirical Analysis of Venture Capital Contracts, *Review of Economic Studies* 70(2), 281-315.

[24] Kaplan, Steven N., and Per Strömberg, 2004, Characteristics, Contracts and Actions: Evidence from Venture Capitalist Analyses, *Journal of Finance* LIX(5), 2177-2210.

[25] Legros, Patrick, and Andrew F. Newman, 2007, Beauty is a Beast, Frog is a Prince: Assortative Matching with Nontransferabilities, *Econometrica* 75, 1073-1102.

[26] Mankiw, N. Gregory, and Michael D. Whinston, 1986, Free Entry and Social Inefficiency, *Rand Journal of Economics* 17(1), 48-58.

[27] Nahata, Rajarishi, 2008, Venture Capital Reputation and Investment Performance, *Journal of Financial Economics* 90(2), 127-151.

[28] Nanda, Ramana, and Rhodes-Kropf, Matthew, 2012, Investment Cycles and Startup Innovation, *HBS Working Paper No. 12-032*.

[29] Perloff, Jeffrey, and Salop, Steven, 1985, Equilibrium with Product Differentiation, *Review of Economic Studies* 52, 107-120.

[30] Repullo, Rafael, and Javier Suarez, 2004, Venture Capital Finance: A Security Design Approach, *Review of Finance* 8, 75-108.

[31] Rosenthal, Robert, 1980, A Model in Which an Increase in the Number of Sellers Leads to a Higher Price, *Econometrica*, 1575-1579.

[32] Samila, Sampsa and Olav Sorenson, 2011, Venture Capital, Entrepreneurship, and Economic Growth, *Review of Economics and Statistics* 93(1), 338-349.

[33] Schmidt, Klaus M., 2003, Convertible Securities and Venture Capital Finance, *Journal of Finance* 58(3), 1139-1166.

[34] Serfes, Konstantinos, 2005, Risk-sharing vs. Incentives: Contract Design under Two-sided Heterogeneity, *Economics Letters* 88, 343-349.

[35] Serfes, Konstantinos, 2008, Endogenous Matching in a Market with Heterogeneous Principals and Agents, *International Journal of Game Theory* 36, 587-619.

[36] Shaked, Avner and John Sutton, 1982, Relaxing Price Competition Through Product Differentiation, *Review of Economic Studies* 49, 3-13.

[37] Shapley, Lloyd S., and Martin Shubik, 1972, The Assignment Game I: The Core, *International Journal of Game Theory* 1, 111-130.

[38] Silviera, Rafael, and Randall Wright, 2006, The Venture Capital Cycle, *Working Paper, University of Pennsylvania*.

[39] Sørensen, Morten, 2007, How Smart is Smart Money? A Two-sided Matching Model of Venture Capital, *Journal of Finance* 62, 2725-2762.

[40] Terviö, Marko, 2008, The Difference that CEOs Make: An Assignment Model Approach, *American Economic Review* 98:3, 642-668.

[41] Ueda, Masako, 2004, Banks versus Venture Capital: Project Evaluation, Screening, and Expropriation, *Journal of Finance* 59, 601-621.

Appendix for Referees

The Efficient (First-Best) VC Contract

We first derive the socially efficient (first-best) VC investment, denoted K^{fb}, and effort of the entrepreneur, denoted e^{fb}.[26] The problem of a social planner can be stated as follows:

$$\max_{\{e,K\}} S(e,K) = \pi(K,\Omega)e - \frac{e^2}{2} - rK, \tag{40}$$

where $S(e,K)$ denotes the total surplus as a function of entrepreneurial effort e and VC investment K. The socially efficient effort level e^{fb} as well as the efficient investment K^{fb} are characterized by the following two first-order conditions:

$$\pi(K,\Omega) = e \tag{41}$$

$$\frac{\partial\pi(\cdot)}{\partial K}e = r. \tag{42}$$

Thus, $e^{fb} = \pi(K^{fb},\Omega)$.[27] Moreover, by substituting (41) into (42) we find that K^{fb} is defined by

$$\frac{\partial\pi(K^{fb},\Omega)}{\partial K} = \frac{r}{\pi(K^{fb},\Omega)}. \tag{43}$$

The optimality condition for $K^M(i)$, (21), is only equivalent to the optimality condition for K^{fb}, (43), when $u^*(i) = (\pi(K,\Omega))^2/2$. However, on the bargaining frontier $\overline{\Pi}(\cdot)$ we have

$$u(i) = \frac{1}{2}\lambda^2\pi^2(K,\Omega) < \frac{1}{2}\pi^2(K,\Omega), \tag{44}$$

because $\lambda < 1$. Thus, $K^M(i) < K^{fb}(i)$ and $e^M(i) < e^{fb}(i)$.

[26] Note that the entrepreneur's equity share λ determines only the allocation of surplus, and not the size of total surplus.

[27] To ensure that $\text{Prob}[Y=1|e^{fb}] = e^{fb} < 1$, we assume that $\pi(K^{fb},\Omega) < 1$ for the socially optimal investment K^{fb} and any possible match quality Ω.