

Competition in the Venture Capital Market and the Success of Startup Companies: Theory and Evidence ^{*}

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Abstract

We examine the effect of a competitive supply of venture capital (VC) on the success rates of VC-backed startup companies (e.g. IPOs). We first develop a matching model of the VC market with heterogenous entrepreneurs and VC firms, and double-sided moral hazard. Our model identifies a non-monotone relationship between VC competition and successful exits: a more competitive VC market increases the likelihood of a successful exit for startups with low quality projects (backed by less experienced VC firms in the matching equilibrium), but it decreases the likelihood for startups with high quality projects (backed by more experienced VC firms). Despite this non-monotone effect on success rates, we find that VC competition leads to higher valuations of all VC-backed startups. We then test these predictions using VC data from Thomson One, and find robust empirical support. The differential effect of VC competition has a profound impact on entrepreneurship policies that promote VC investments.

Keywords: entrepreneurship, venture capital, matching, double-sided moral hazard, exit, IPO.

JEL classifications: C78, D86, G24, L26, M13.

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1 Introduction

Over the last three decades venture capital (VC) became an increasingly important source of startup funding for entrepreneurs with innovative products. For example, the number of VC firms has more than quadrupled in the US: while 408 VC firms actively invested in startup companies in 1991, this number rose to 1,639 in 2015 (Thomson One). At the same time a substantially larger number of startup companies received VC financing: 970 companies in 1991 versus 3,743 in 2015 (Thomson One). On the one hand, the list of successful and well-known companies that received VC at some point during their startup phase includes Google, Facebook, Airbnb, and Uber. On the other hand, many startups received VC but eventually failed, for example Pets.com, eToys, Jawbone, and many others. Overall, this suggests a substantial heterogeneity of startup companies with respect to their market potentials.

Governments around the globe have implemented various policies to spur VC investments (e.g. capital gains holidays, R&D subsidies etc.), which has contributed significantly to the rise of venture capital (e.g. Gompers and Lerner (1998)). Clearly, startup companies that would have otherwise not received VC funding benefit from a more competitive VC supply. However, in this paper we pursue a more nuanced approach, and examine, both theoretically and empirically, whether a more competitive supply of capital has a differential impact on the funded companies, depending on their underlying ‘quality’. For this, we focus on two key variables that are critical for entrepreneurs, investors, and policy makers alike: the valuation of startup companies, and their likelihood to experience a successful exit (IPO).

To analyze the relationship between the supply of VC, and the valuation and success rate (or IPO rate) of startup companies, we first develop an equilibrium model of the VC market with two-sided heterogeneity, matching, and double-sided moral hazard.¹ In our model, entrepreneurs (ENs) and venture capital (VC) firms are vertically heterogenous with respect to the quality of their business ideas (ENs), and their experience or management expertise (VC firms). In equilibrium, entrepreneurs with high quality projects match with high quality VC firms (positive assortative matching). Each VC firm then provides capital in exchange for an equity stake, which in turn determines the valuation of the startup company. Moreover, for a given match, both the entrepreneur and the VC firm (as an active investor) need to exert private effort to bring the entrepreneurial project to fruition.² The joint effort then determines the probability for the venture to generate a positive payoff (double-sided moral hazard).

¹There is ample empirical evidence that the VC market is characterized by both sorting (see, e.g., Sørensen (2007)) and double-sided moral hazard (see, e.g., Kaplan and Strömberg (2003)).

²VC firms typically take an active role when investing in startup companies. Their so-called *value-adding services* include mentoring, conducting strategic analyses, and recruiting managers (e.g. Sahlman (1990), Gorman

Our theory reveals a differential effect of a more competitive VC supply: it improves the success rate of low quality entrepreneurial projects (backed by less experienced VC firms), while it deteriorates the success rate of high quality projects (backed by more experienced VC firms). Despite this differential effect, the model shows that more intense VC competition improves the equilibrium valuation of *all* startup companies.

The key mechanism behind our main insights is as follows. For each EN-VC pair, as is standard in double-sided moral hazard models, there exists a specific allocation of equity that harmonizes the effort incentives between the two sides and maximizes the probability of a successful exit (IPO). However, we show that in the matching equilibrium, due to competition among VCs for high quality ENs, entrepreneurs with high quality projects (backed by more experienced VC firms) hold ‘too much’ equity. This implies insufficient effort incentives for the VC firm, and more importantly, this is inefficient from a joint perspective as it does not maximize the venture’s probability of success. The opposite is true for entrepreneurs with low quality projects (backed by less experienced VC firms): they retain ‘too little’ equity in equilibrium, so their effort incentives are also inefficient from the perspective of maximizing the likelihood of a successful exit.

Stronger competition among VC firms (i.e., a lower market concentration), forces all matched VC firms to provide funding in exchange for less equity. This implies a higher valuation of all startup companies, regardless of whether they have high or low quality projects. However, leaving entrepreneurs with high quality projects with more equity, exacerbates the inefficient equity allocation (which is tilted in favor of entrepreneurs), and therefore further diminishes the joint efficiency of effort incentives. As a result, ventures with high quality projects (backed by more experienced VC firms) are then less likely to have a successful exit. We find the opposite for ventures with low quality projects (backed by less experienced VC firms): more equity for entrepreneurs (i.e., higher valuations), partially offsets the initial inefficiency associated with unbalanced effort incentives, and therefore improves the likelihood of a successful exit.

We then test our theoretical predictions using VC investment data from Thomson One (formerly called VentureXpert), covering all investments in the US from 1991 to 2010.³ For this, we define VC markets based on the geographical locations of the portfolio companies (using the metropolitan statistical areas), and industries.⁴ Moreover, to measure VC market concentra-

and Sahlman (1989), and Lerner (1995)). Moreover, Bottazzi et al. (2008) provide empirical evidence that an active involvement of the VC firm has a positive effect on the success rate of their portfolio companies.

³We end our sample in 2010 to leave sufficient time to observe exit results of portfolio companies.

⁴Thomson One divides start-up companies into six major industry groups: Communications and Media, Computer Related, Semiconductors and Other Electronics, Biotechnology, Medical, Health and Life Sciences, and Non-High Technology.

tion (or the degree of VC competition) we use (i) the Herfindahl-Hirschman index, and (ii) the inverse number of VC firms in a given market.

We find strong empirical support for our theoretical predications: a more competitive supply of VC improves the IPO rates of portfolio companies backed by less experienced VC firms, and impairs the IPO rates of companies backed by more experienced VC firms (where experience is measured by the number of prior investments). Given the empirically documented positive assortative matching (Sørensen (2007)), this suggests that VC competition has a negative effect on the IPO rates of high quality startup companies, and a positive effect on the IPO rates of lower quality startups.⁵ Despite this differential effect on IPO rates, we find that more VC competition (or lower market concentration) leads to higher valuations of all VC-backed startups.

The literature on the structure of VC markets is small. Hochberg et. al. (2015) examine VC market competition by accounting for a particular type of product differentiation: the choice to be a specialist or a generalist investor. They find that, unlike in other industries, in the VC industry the incremental effect of additional same-type competitors increases as the number of same-type competitors increases. They attribute this finding to the presence of strong network effects within the VC industry. Gompers et. al. (2009) look at the success of VC investments, and how it is affected by industry specialization. They show that more specialized VC firms are more likely to succeed.

Our theory model is close in spirit to the search models of entrepreneurial finance, as devised by Inderst and Müller (2004), Hellmann and Thiele (2015), and Silveira and Wright (2016). Although these papers assume frictions in the matching process, while we assume a frictionless environment, the main qualitative difference is our assumption of ex-ante heterogeneity. Inderst and Müller (2004) and Hellmann and Thiele (2015) consider homogenous VC firms and entrepreneurs, while Silveira and Wright (2016) introduce ex-post heterogeneity, i.e., the heterogeneity arises after a VC firm is matched with an entrepreneur. We show that it is the heterogeneity in our model (in conjunction with double-sided moral hazard) that leads to the differential effect of VC competition on the likelihood of new ventures to succeed (which we also find empirical support for). Our paper is also related to Jovanovic and Szentes (2012), who consider random matching within a VC context with ex-post heterogeneity, to examine the link between excess returns and the scarcity of VC firms.

Sørensen (2007) empirically investigates how the experience of VC firms affects the likelihood of startup companies to go public. He distinguishes between the sorting effect (more experienced VC firms invest in better projects), and the treatment affect (more experienced VC

⁵We can also interpret this finding as empirical evidence for the existence of double-sided moral hazard between entrepreneurs and their investors.

firms provide better value-adding services). Estimating a structural two-sided matching model, he shows that the sorting effect is almost twice as important as the treatment effect in explaining observed differences in IPO rates across portfolio companies. Bengtsson and Hsu (2015) look at a different type of sorting in the VC industry, based on human and social characteristics of entrepreneurs and VC partners. They provide empirical evidence that belonging to the same ethnicity increases the likelihood of a match.

An important feature of our model is that both parties in a given match (the entrepreneur and the VC firm) need to apply private effort to bring the project to fruition. This leads to a typical double-sided moral hazard problem, which is a key driver for the differential effect of VC competition on the success rates of startup companies. Casamatta (2003), Schmidt (2003), Repullo and Suarez (2004), and Hellmann (2006), also consider a double-sided moral hazard problem within the context of entrepreneurial finance. However, these papers focus on the optimal security design for a single entrepreneur-investor pair, while we consider simple equity contracts (similar to Keuschnigg and Nielsen (2004)). Moreover, we consider endogenous matching in a market setting with multiple entrepreneurs and VC firms.

The remainder of this paper is structured as follows. Section 2 introduces the theoretical model and discusses its main predictions. Section 3 describes the data and presents our empirical results. Section 4 summarizes our key insights and concludes. All proofs and regression tables are in the Appendix.

2 Theoretical Model and Results

2.1 Main assumptions

We consider a market consisting of a continuum of risk-neutral and wealth-constrained entrepreneurs (ENs) of mass one, and a continuum of risk-neutral venture capital firms (VC firms) of mass one. ENs differ in terms of the quality (or market potential) of their projects. We index ENs by $i \in E = [0, \bar{i}]$, with $H(i)$ as the distribution of i , and $h(i)$ as its density. A higher index i indicates a higher project quality. Likewise, VC firms differ in terms of their investment experience (and therefore management expertise). We index VC firms by $j \in V = [0, \bar{j}]$, with distribution $G(j)$ and density $g(j)$. A higher index j indicates a more experienced VC firm (with a higher management expertise). The quality of entrepreneurial projects (i) and VC firm experience (j) are common knowledge.

There are five dates; see Figure 1 for a graphical overview. At date 1, EN i conceives an innovative business idea of quality i . To commercially exploit his idea, each entrepreneur

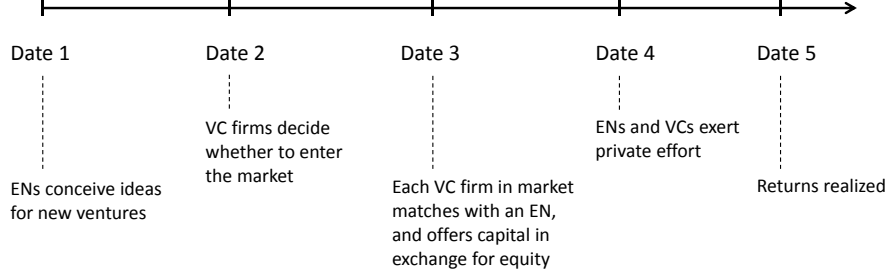


Figure 1: Timeline

requires capital K from a VC firm. 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 EN. VC firm j then offers its entrepreneur i capital K in exchange for an equity stake s_{ij} in the company. The EN retains the remaining equity share $(1 - s_{ij})$.⁶ The cost of capital faced by each VC firm is $r > 0$. The utility of an EN who remains unmatched is $u \geq 0$.

At date 4, each EN and VC exert private efforts e_i and v_j respectively, to turn the idea into a marketable product. The non-contractibility of both efforts leads to a typical double-sided moral hazard problem between ENs and VCs. The combined effort levels determine the likelihood of whether the venture succeeds ($Y = 1$) or fails ($Y = 0$), where $\Pr[Y = 1 | e_i, v_j] \equiv \rho = e_i^\phi v_j^{1-\phi}$. This implies that both efforts are complements, and that the startup can only succeed if both the EN and the VC apply effort. Moreover, the parameter $\phi \in (0, 1)$ measures the relative importance of the entrepreneur's effort e_i relative to the VC's effort v_j . Intuitively, the entrepreneur's effort e_i is at least as important as the VC firm's effort v_j , to bring the project to fruition, i.e., $\phi \geq 1/2$. The entrepreneur's disutility of effort is $e_i/2$, and the VC's disutility of effort is given by $v_j/2$.

If the venture succeeds it generates the, continuously differentiable, payoff $\pi(i, j)$ at date 5. Intuitively, a higher project quality i or more VC experience j leads to a higher payoff. Formally we assume that $\pi_i, \pi_j > 0$, where π_k denotes the partial derivative of $\pi(i, j)$ with respect to $k = i, j$. Moreover, we assume that project quality and VC experience are (weak) strategic complements, i.e., $\pi_{ij} \geq 0$. In case of failure the venture generates a zero payoff.

The equity stake obtained by a VC firm, s , in exchange for investing K , determines the valuation of the startup company. The so-called post-money valuation is defined by $\Omega_{post} \equiv K/s$, while the pre-money valuation is given by $\Omega_{pre} \equiv \Omega_{post} - K$. We follow the convention in

⁶To ensure tractability of our matching model, we do not consider separate financing rounds. We thus interpret K as the cumulative venture capital invested in a startup company.

the empirical VC literature and use pre-money valuations throughout this paper (including our theory). Both valuation measures are obviously equivalent.

To keep our model as simple and transparent as possible, we focus in our main text on the allocation of equity as the only contracting tool between ENs and VC firms. In some cases, however, it may be Pareto improving if a VC firm makes a monetary transfer payment to its EN (in addition to providing K), in order to buy some additional equity. In Section A.6 in the Appendix we show that allowing for additional transfer payments does not change our main results, as long as there is a cost (even if very small) to making such transfers (e.g. income taxes or financial intermediation costs).

2.2 Contracts in the absence of matching

We first consider the contractual relationship between an arbitrary EN-VC pair, ignoring for now any effects arising from the matching process between heterogenous ENs and VC firms. The analysis in this section therefore closely resembles those in Repullo and Suarez (2004), Inderst and Müller (2004), and Hellmann (2006), for the optimal sharing rule for a single EN-VC pair. We proceed in three steps: First, we derive the equilibrium effort levels for the EN and the VC firm for a given allocation of equity. Second, we characterize the utility-possibility frontier, and identify the feasible payoff allocations. For this we derive (i) the allocation of equity preferred by the VC firm, (ii) the equity allocation preferred by the EN, and (iii), the jointly optimal (i.e., Pareto efficient) allocation of equity. Third, we characterize the equilibrium allocation of equity as a function of the entrepreneur's outside option (which will be endogenous when allowing for matching). For parsimony we suppress subscripts whenever possible.

Let U^E and U^V denote the expected utility for the EN and the VC firm, respectively. For a given sharing rule s , the EN and VC firm choose, simultaneously and independently, efforts e and v to maximize their expected utilities:

$$\max_{\{e\}} U^E(e; s, v) = e^\phi v^{1-\phi} (1-s) \pi - \frac{e^2}{2} \quad (2.1)$$

and

$$\max_{\{v\}} U^V(v; s, e) = e^\phi v^{1-\phi} s \pi - \frac{v^2}{2}. \quad (2.2)$$

We show in Section A.1 in the Appendix that for a given sharing rule s , the EN and the VC firm choose the following effort levels:

$$e(s) = [(1-\phi) s]^{\frac{1-\phi}{2}} [\phi (1-s)]^{\frac{(1+\phi)}{2}} \pi, \quad v(s) = [\phi (1-s)]^{\frac{\phi}{2}} [(1-\phi) s]^{\frac{2-\phi}{2}} \pi.$$

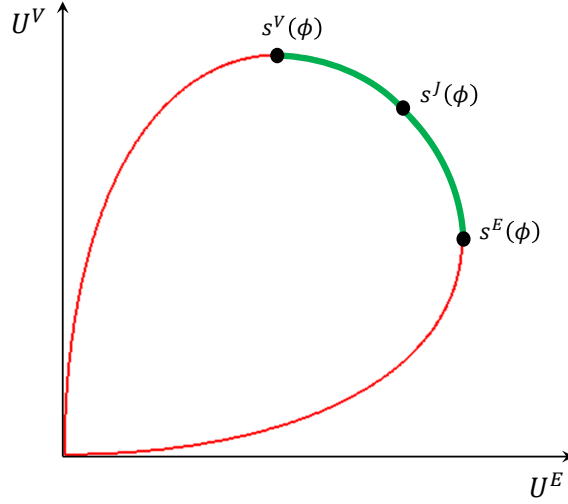


Figure 2: Utility-possibility frontier

Moreover, using $e(s)$ and $v(s)$ we show that the equilibrium success probability is given by

$$\rho(s) = [(1 - \phi) s]^{1-\phi} [\phi (1 - s)]^\phi \pi.$$

The next Lemma characterizes some important properties of the utility-possibility frontier, which is an important stepping stone towards establishing the matching outcome in Section 2.3. Its proof is in Section A.2 in the Appendix.

Lemma 1 *Consider an arbitrary EN-VC pair in the absence of endogenous matching. The utility-possibility frontier has the following properties:*

- (i) *The VC firm's expected utility U^V is maximized for the sharing rule $s = s^V \equiv \frac{1}{2} (2 - \phi)$.*
- (ii) *The EN's expected utility U^E is maximized for the sharing rule $s = s^E \equiv \frac{1}{2} (1 - \phi)$.*
- (iii) *The Pareto efficient sharing rule, which maximizes the joint utility $U^V + U^E$, is $s = s^J \equiv 1 - \phi$. For $s = s^J$ the success probability $\rho(s)$ is also maximized.*

For any $s \in [s^E, s^V]$ the corresponding payoff allocation is feasible, with $s^E < s^J < s^V$.

Figure 2 illustrates the utility-possibility frontier (UPF) for all sharing rules $s \in [0, 1]$. Both the EN and the VC firm need to exert private effort to generate a positive expected payoff. If one party gets the entire equity ($s \in \{0, 1\}$), the other party will not exert any effort, so that the project fails and generates a zero payoff ($U^V = U^E = 0$). As a result the UPF is backward bending. We can see from Figure 2 that the joint utility, and likewise the success probability

$\rho(s)$, is maximized for $s = s^J$. However, the EN and the VC firm each prefer more equity, which is optimal from an individual perspective, but inefficient from a joint perspective. Lemma 1 also implies that in equilibrium both parties will settle on any sharing rule $s \in [s^E, s^V]$, which is reflected by the green portion of the UPF in Figure 2 ($s \in [s^V, s^E]$).⁷ Along this green portion, a higher expected utility for the EN (U^E) implies a lower expected utility for the VC firm (U^V), which is attained by allocating less equity to the VC firm (i.e., both parties agree on a lower s). The feasible portion of the utility-possibility frontier for EN i and VC firm j , denoted $UPF(i, j)$, is then defined by

$$UPF(i, j) = \{ (U^E(s; i, j), U^V(s; i, j)) : s \in [s^E, s^V] \}.$$

We can now characterize the main properties of the equilibrium sharing rule s^* for a given EN-VC pair. For this we denote the EN's reservation utility by u . Specifically, the VC firm offers capital K in exchange for the equity stake $s^*(u)$, which maximizes its expected utility $U^V(s)$, subject to the EN's participation constraint $U^V(s) \geq u$. The next lemma identifies the main properties of $s^*(u)$. Its proof is in Section A.3 in the Appendix.

Lemma 2 *There exists a threshold reservation utility u' for the EN, so that $s^*(u) = s^V$ for $u \leq u'$. For $u > u'$, the optimal sharing rule $s^*(u) \in [s^E, s^V)$ satisfies $U^V(s) = u$, and is decreasing in u (i.e., $ds^*(u)/du < 0$ for $u > u'$).*

If the EN has a sufficiently low outside option ($u \leq u'$), then the VC firm can implement its own preferred sharing rule s^V . This would still provide the EN with a higher expected utility compared to his next best alternative ($U^E(s^V) \geq u$). However, the sharing rule s^V would violate the EN's participation constraint if his outside option is sufficiently attractive ($u > u'$). The VC firm is then forced to offer the EN more utility by taking less equity in the company, so that $s^*(u) < s^V$. And a more attractive outside option implies that the EN can retain more equity in his company in equilibrium ($ds^*(u)/du < 0$ for $u > u'$).

2.3 Market equilibrium

We now characterize the equilibrium outcome in a two-sided market with heterogenous ENs and VC firms. We proceed in two steps. In Section 2.3.1 we derive the conditions that ensure a

⁷Note that the shape of the UPF is determined by the relative productivity parameter ϕ . If $\phi = 1/2$ then the UPF is symmetric around the 45 degree line, with $s^E = 1/4$, $s^V = 3/4$, and $s^J = 1/2$.

positive assortative matching equilibrium. We then examine in Section 2.3.2 the effect of competition in the VC market on (i) the equilibrium allocation of equity (or pre-money valuations of start-up companies), and (ii) the equilibrium success rate of new ventures.

2.3.1 Positive assortative matching

We now define the equilibrium of the VC market when each VC firm matches with one entrepreneur (*one-to-one matching*).⁸ The reservation utility of each EN, u , is then *endogenously* determined by potential contract offers from alternative VC firms. Moreover, note that the VC firm's expected utility $U^V(s)$ depends on the implemented sharing rule s , and according to Lemma 2, the equilibrium sharing rule $s^*(u)$ is a function of the EN's outside option u . We denote the expected utility of VC firm j , when matched with EN i with outside option $u(i)$, by $U^V(i, j, u(i))$.

We now state two important characteristics of the matching equilibrium.

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 $U^{V*} : V \rightarrow \mathbb{R}_+$ and $U^{E*} : E \rightarrow \mathbb{R}_+$, that satisfy the following two conditions:*

- (i) *Feasibility of (U^{V*}, U^{E*}) with respect to m : For all $i \in E$, $\{U^{V*}(m(i)), U^{E*}(i)\}$ is on the feasible utility-possibility frontier $UPF(i, j)$.*
- (ii) *Stability of m with respect to $\{U^{V*}, U^{E*}\}$: There do not exist a pair $(i, j) \in E \times V$, where $m(i) \neq j$, and outside value $u(i) > U^{E*}(i)$, such that $U^V(i, j, u(i)) > U^{V*}(j)$.*

The *feasibility* condition requires that the payoffs for VC firms and ENs are attainable, which is guaranteed whenever the payoffs for any pair $(i, m(i))$ are on the feasible utility-possibility frontier. 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 have a positive assortative matching equilibrium (PAM) whenever entrepreneurs with high quality projects match with high-experience VC firms. Applying the criteria derived by Legros and Newman (2007) for an imperfectly transferable utility (ITU) case, our matching equilibrium is positive assortative if and only if the *generalized increasing differences* condition

⁸While 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' experience j .

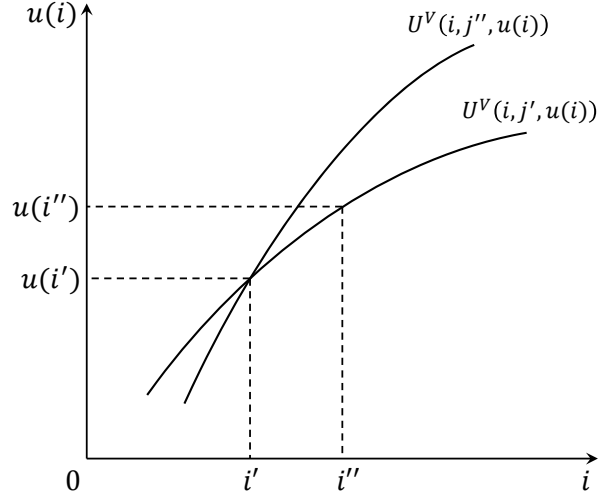


Figure 3: The single-crossing property

holds (GID). The GID condition is equivalent to a single-crossing property (Chade et. al., 2017). The idea is as follows. Consider two VC firms j'' and j' , with $j'' > j'$, and two ENs i'' and i' , with $i'' > i'$. Assume that VC j' is indifferent between $(i', u(i'))$ and $(i'', u(i''))$, so both of these points lie on VC j' 's indifference curve. Then, VC j'' is better off matching with i'' and offering the utility $u(i'')$ than matching with i' and offering the utility $u(i')$. More formally,

$$U^V(i', j', u(i')) = U^V(i'', j', u(i'')) \Rightarrow U^V(i'', j'', u(i'')) > U^V(i', j'', u(i')). \quad (\text{GID})$$

The single-crossing property is illustrated by Figure 3. Specifically, point $(i'', u(i''))$ lies on a higher indifference curve of VC j'' than point $(i', u(i'))$, while both points lie on the same indifference curve of VC j' , with $j'' > j'$. Consequently, if (GID) holds, the higher quality VC firm j'' can always outbid the lower quality VC firm j' for the higher quality EN i'' . Formally, (GID) holds as long as the slope of a VC firm's indifference curve is increasing in its own type. We show in Section A.4 in the Appendix that the slope of VC j 's indifference curve in the (i, u) space is given by

$$\Psi(i, j) \equiv -\frac{U_i^V(i, j, u)}{U_u^V(i, j, u)} = 2\frac{\pi_i}{\pi} \frac{1}{2 - 2s(u) - \phi} u, \quad (2.3)$$

where U_k^V denotes the partial derivative of U^V with respect to $k = i, u$, and $s(u)$ is derived (implicitly) from the EN's participation constraint, see (A.6). We can see that $\Psi(i, j)$ is strictly positive for all $s^* \in [s^E, s^V)$. Moreover, in Section A.4 in the Appendix we prove that $d\Psi(i, j)/dj > 0$. This implies that the stable matching outcome is positive assortative (PAM).

2.3.2 The effects of VC competition

We now turn to the main objective of our theory, namely identifying the effects of competition among VC firms on (i) the allocation of equity between VC firms and entrepreneurs (or the pre-money valuation of startup companies), and (ii) the success rate of new ventures.

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 equilibrium. 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 $m(i)$:

$$\frac{dm(i)}{di} = G^{-1'}(H(i)) h(i) = \frac{h(i)}{G'(G^{-1}(H(i)))} = \frac{h(i)}{g(m(i))}. \quad (2.4)$$

This says that the slope of the matching function $m(i)$ is equal to the ratio of the densities of EN and VC types, $h(i)$ and $g(m(i))$.

The next lemma characterizes the equilibrium utility $U^{E*}(i)$ of entrepreneur i .

Lemma 3 *The equilibrium utility $U^{E*}(i)$ for EN i is characterized by the ordinary differential equation*

$$\frac{dU^E(i)}{di} = -\frac{U_i^Y(i, m(i), U^E(i))}{U_u^V(i, m(i), U^E(i))} = \frac{2\pi_i(i, m(i))}{\pi(i, m(i))} \frac{U^E(i)}{(2 - 2s(U^E(i)) - \phi)} > 0 \quad (2.5)$$

with the initial condition $U^E(\underline{i}(F)) = \max\{U^E(s^V; \underline{i}, m(\underline{i})), \underline{u}\}$.

Equation (2.5) is derived from (2.3) by setting $j = m(i)$ and replacing u with U^E . It implies that as i increases, j also increases according to the equilibrium matching function. By construction, (2.5) guarantees that VC firm j maximizes its expected utility over all possible i 's, given $U^E(i)$, only when it matches with $i = m(j)$. From the stability requirements, it then follows that $U^{E*}(i)$ and $U^{V*}(i)$ are increasing in i .

We assume that $U^E(\underline{i}(F)) = \max\{U^E(s^V; \underline{i}, m(\underline{i})), \underline{u}\} = \underline{u}$. This implies that every unmatched EN has a reservation utility \underline{u} higher than the minimum expected utility he receives in the PAM equilibrium (so that $s^E \leq s^*(u) < s^V$). The unique solution $U^{E*}(i)$ to (2.5) must then (implicitly) satisfy⁹

$$U^{E*}(i; F) = \underline{u} + \int_{\underline{i}(F)}^i \frac{dU^{E*}(s)}{ds} ds, \quad (2.6)$$

⁹As is typical in these models, a closed form solution for $U^{E*}(i)$ does not exist. Nevertheless, in Section A.5 in the Appendix we show that a unique (numerical) solution must exist.

where $\underline{i}(F)$ is the EN that receives funding from the marginal VC firm \underline{j} in the matching equilibrium.

The marginal VC firm \underline{j} gets a zero expected utility from entry, i.e., $U^{V*}(m(i)) - rK - F = 0$. If the entry cost F decreases, then more VC firms enter the market and match with previously unmatched ENs, so that $\underline{i}(F)$ decreases (i.e., $d\underline{i}(F)/dF > 0$).

We can now examine how more competition in the VC market affects contracts and success rates in the matching equilibrium. Technically, we can vary the entry cost F to change the equilibrium number of VC firms in the market, and therefore the degree of competition. Suppose the entry cost F decreases, so that more VC firms enter the market and match with previously unmatched ENs. Because of PAM, all the previous EN-VC matches remain the same; however, VC entry affects the outside option of each EN in the market, and therefore the equity allocation (or the pre-money valuation). By differentiating (2.6) we obtain

$$\frac{dU^{E*}(i; F)}{dF} = -\frac{dU^{E*}(\underline{i}; F)}{d\underline{i}} \frac{d\underline{i}}{dF} < 0.$$

Lower entry costs, and therefore more competition among VC firms, leads to higher expected utility levels for all ENs in equilibrium. A higher expected utility in turn is rooted in each EN retaining a higher equity share in his company (so that s^* decreases). For EN-VC pairs with $s^* > s^J$, which have the lower quality projects, this implies a higher probability $\rho(s^*)$ for the venture to succeed. Given that the jointly optimal share, $s^J = 1 - \phi$, is not a function of i , and $U^{E*}(i)$ is increasing in i , via higher share to higher quality ENs and so a lower s^* , for high enough heterogeneity, there must exist a threshold VC-EN pair above which the share given to the EN exceeds the jointly optimal level. In this case, the pairs with $s^* < s^J$, which have the higher quality projects, experience a lower success probability $\rho(s^*)$. We summarize these insights in the next proposition.

Proposition 1 *Suppose the fixed entry cost F decreases so that more VC firms enter the market. Then, there exists an $\hat{i} \in [\underline{i}, \bar{i}]$ such that:*

- (i) *For all $(i, m(i)) \ll (\hat{i}, m(\hat{i}))$, the probability of success $\rho(s^*)$ increases.*
- (ii) *For all $(i, m(i)) \gg (\hat{i}, m(\hat{i}))$, the probability of success $\rho(s^*)$ decreases.*
- (iii) *All VC-backed ENs retain more equity, which implies higher pre-money valuations.*

A key insight is that the quality of the VC firm matters for whether competition has a positive or a negative effect on the success probability for its portfolio company. We know from Lemma

1 that a startup company is most likely to succeed when the efforts of both, the EN and the VC firm, are “balanced”, which is achieved when the equity stakes (and hence the incentives for effort), are balanced. This is the case whenever $s^* = s^J$; see Figure 2. However, the equilibrium sharing rule s^* depends on the actual match quality (i, j) , and the next best alternative for the entrepreneur. And we know from Lemma 2 that a more attractive outside option implies that the EN can retain more equity in his company ($ds^*(u)/du < 0$), so that a given EN-VC pair “moves down” on the green portion of the utility-possibility frontier in Figure 2.

In a positive assortative matching equilibrium, only high quality VC firms match with high quality ENs. The equity allocation in these relationships is already tilted in favor of ENs due to strong competition among VCs for the high quality projects, and so VC firms exert insufficient effort from a joint perspective (as $s^* < s^J$). Now with increased competition these high quality VC firms are forced to leave their ENs with even more equity (i.e., they need to offer higher valuations), so the equity allocation becomes even more tilted in favor of ENs. This provides yet more effort incentives to ENs, but further curbs effort incentives for VC firms. The net effect of this imbalance is that the startup becomes less likely to succeed (i.e., $\rho(s^*)$ decreases). By contrast, the equity allocation for low quality EN-VC pairs is inefficiently tilted in favor of VC firms. More competition then (partially) corrects this inefficiency by forcing a VC firm to leave its EN with more equity. This in turn makes low quality ventures more likely to succeed.

Inderst and Müller (2004), Proposition 3, show that stronger competition in the VC market, defined in a similar way as in our model, first increases and then decreases the probability of success. We would obtain the same result if VCs and ENs were homogeneous and we exogenously increased the EN’s outside option u . For low u (interpreted as a concentrated VC market) the success probability would increase and for high u (competitive VC market) it would decrease. Our theoretical contribution is that we differentiate between high and low quality VC-EN pairs and show that the non-monotonicity identified by Inderst and Müller (2004) can *co-exist* in the market and competition can have a differential effect on start-ups.

The second main insight is related to a known result from the endogenous matching literature (see, e.g., Terviö (2008)). Specifically, each VC firm offers its EN just enough utility to prevent being outbid by the marginally lower VC firm. More competition then forces VC firms to transfer more utility to their ENs. Within our context, this means that VC firms ask for less equity when investing in startup companies, implying higher pre-money valuations in equilibrium.

3 Empirical Analysis

In this section we empirically test the predictions from our endogenous matching model pertaining to the effect of VC competition on the success rate and valuations of startup companies. Specifically, we test the following two hypotheses which follow directly from Proposition 1:

Hypothesis 1: *Suppose the VC market becomes more competitive (i.e., industry concentration decreases). Then, the pre-money valuations of all VC-backed companies increase.*

Hypothesis 2: *Suppose the VC market becomes more competitive. Then, the probability of a successful IPO for the high quality companies decreases, while the probability for the low quality companies increases.*

3.1 Data

We use the VC investment data from the Thomson One database (formerly called VentureXpert). This comprehensive database has been extensively used in VC research (see, e.g., Kaplan and Schoar (2005), Sørensen (2007), and Samila and Sorenson (2011)). Thomson One provides detailed information on VC-backed companies, which includes the dates and investment amounts for different financing rounds, the identities of investing VC firms, the development stage and industry groups of portfolio companies, and the dates and types of an exit (e.g., IPO, acquisition, or liquidation).

It is well known that VC firms specialize in specific industries and tend to invest in local startup companies (e.g., Sørensen (2007) and Hochberg et al. (2010)). We therefore define VC markets as follows: First, we differentiate among the six main industry groups in the Thomson One database. These include “Communications and Media,” “Computer Related,” “Semiconductors and Other Electronics,” “Biotechnology,” “Medical, Health and Life Sciences,” and “Non-High-Technology.” Second, for each industry, we group all companies located in the same US Metropolitan Statistical Area (MSA). For example, “Computer Related” in the MSA of Philadelphia-Camden-Wilmington is a different market from “Biotechnology” located in Greater Boston. To improve the explanatory power of our regression analysis, we exclude all observations for inactive market periods. This concerns markets with either fewer than five deals in the current year, or fewer than 25 deals in the past five years. Moreover, we exclude funding rounds that are in the stage of buyouts and drop deals led by corporate venture capital (CVC) firms. Unlike independent VC firms that are primarily focused on the financial returns from their investments, CVCs also seek to achieve strategic objectives, such as gain-

ing access to entrepreneurial innovations and exploring emerging business opportunities. As a result, compared to independent VC firms, CVCs usually provide higher investment amounts and show greater tolerance for failure; see Gompers and Lerner (2000), and Guo et al. (2015). However, all of our results remain robust to including CVC-backed deals.

VC investments are typically made in stages; this allows investors to closely monitor the progress of the portfolio company before providing follow-on funding (see Gompers (1995) and Tian (2011)). Consequently, the financing terms at later rounds are largely affected by information previously obtained by VC firms. We therefore focus on the initial funding rounds to ensure that *ex ante* no VC firms have superior access to information that may affect the financing terms. The status of the companies is current as of December 2016, and we restrict the sample to initial rounds of investments made between 1991 and 2010, leaving at least 7 years for firms to exit. The final sample contains a total of 5,254 VC firms investing in 12,670 portfolio companies that received their initial funding in the US between 1991 and 2010.

3.2 Variables

Market Level Measures

We use two alternative measures of market concentration: the Herfindahl-Hirschman Index (HHI) and the inverse number of VC firms in a given market. Our HHI accounts for the deal shares of VC firms in a given market and year.¹⁰ When multiple VC firms participate in a financing round (syndication), we split the total investment amount equally (as Thomson One does not report individual investment amounts). Table 1 reports the summary statistics for our market concentration measures. At the mean, there are about 10 VC firms investing in a given market and year.

We also measure the connectedness of VC firms at the market level, following Hochberg et al. (2010). For each market and year combination, we consider syndication relationships among all the investing VC firms over a five-year time window ending in $t - 1$. With n investors, there are at most $\frac{1}{2}n(n - 1)$ possible ties formed through syndication. We then track the actual

¹⁰Thomson One only reports overall investment amounts received by a portfolio company from a given VC firm, but does not disclose round-level amounts raised from individual VC firms. As a result, we are not able to compute the HHI based on the investment amounts for a given market-year. However, as a robustness check we attribute the total amounts invested by a given VC firm to all the rounds that this VC firm participated in, accounting for the size of the funding round. We then calculate the HHI based on the attributed investment amounts. For example, suppose a startup company received in total \$1 million from VC_i that participated in rounds 1 and 3. If the total amounts raised in rounds 1 and 3 are \$1 million and \$3 million dollars, respectively, then the investment in round 1 attributed to VC_i is $1/(1 + 3) = 0.25$ million, and in round 3 $3/(1 + 3) = 0.75$ million. The HHI based on the attributed investment amounts is highly correlated with the deal-based HHI, and the estimation results are qualitatively similar. For parsimony we only report results using the deal-based HHI.

syndication relationships in all markets within the five-year window. The market level network measure is then defined as the ratio between the actual number of ties and the highest possible number ties.

Portfolio Company Performance Measures

We use a portfolio company's IPO status to measure success. Naturally it takes several years for a company to go public after its initial investment. Thus, we restrict our sample to all the investments made between 1991 and 2010. As we extract the data in December 2016, this leaves us with at least a seven-year time window to identify the IPO status of a portfolio company. Our performance measure, IPO, is binary and is equal to one if a company eventually goes public.¹¹ We do not use mergers and acquisitions (M&As) to measure successful exits. Many M&A deals take place simply because the portfolio company possesses assets that an acquirer may want, so M&As tend to be noisy indicators of success.

Other Portfolio Company Characteristics

Thomson One provides information about the development stage of a portfolio company at each financing round. We use this information to create four dummy variables that indicate four distinct development stages of a company: "Seed," "Early Stage," "Later Stage," and "Expansion." The default development stage of a company is "Other." The age of a company is the number of years since it was founded, up to the date of a given financing round. To control for the unobservable quality of its business project, we use the investment amount raised by the portfolio company in the current round. Moreover, "Round number of investors" is the number of VC firms investing in the current round.

VC Firm Characteristics

We control for the characteristics of lead investors in a given financing round. For this we identify the VC firm that made the highest investment in the portfolio company (see Tian (2011)). We use the fund size and the experience of a VC firm as control variables. If fund size information is missing, we use the average size of all other funds managed by the same VC firm. To measure the experience of a VC firm, we use the total number of its prior investments.¹²

¹¹We also construct a short-term performance measure, "Survival", that captures whether a portfolio company survived and received subsequent financing (which requires the company to have reached certain business milestones). We use this measure as an interim signal of success, and find qualitatively similar results for our regressions (unreported).

¹²Nahata (2008) proposes the following two alternative measures for VC experience: (i) the cumulative market capitalization of IPOs backed by a VC firm, (ii) a VC firm's share of the aggregate investment in the VC industry. Since we do not have round-level investment amounts for individual VC firms, we are not able to construct investment shares for each individual VC firm. However, we use another experience measure based on a VC firm's capitalization share of IPOs, and find that our main results remain robust.

3.3 The Effects of Concentration on Pre-money Valuations

3.3.1 Identification Strategy

Our theory predicts that higher market concentration (i.e., less competition) implies lower pre-money valuations of startup companies (Hypothesis 1). However, the impact of market concentration is subject to endogeneity concerns. Unobservables about portfolio companies may correlate with market concentration and, at the same time, affect their valuations, leading to omitted variable bias. To control for the endogeneity of market concentration, we need an instrument that satisfies two conditions: First, the instrument affects competition among VC firms in a given market. Second, the instrument is exogenous to unobservables that affect company valuation.

For our instrument we utilize variations in venture capital supply that are caused by return variations for the portfolios of limited partners (LPs). We also exploit the regional and industry heterogeneity of VC activities to identify market-level variations. More specifically, we use an augmented version of the instrumental variable used by Samila and Sorensen (2011), which is based on three salient features of the VC industry: First, institutional investors constantly adjust their investment portfolios, which affects the supply of venture capital. These investors include pension funds, insurance companies, and university endowments. For example, when university endowments realize a higher return, fund managers increase the amount of capital they invest in different asset classes, including venture capital. An increase in the supply of capital, in turn, affects the competition landscape in the VC industry. Second, institutional investors tend to invest in local VC firms (Hochberg and Rauh, 2013). Third, there is consistency over time with regards to the composition of the VC industry in a given geographic location.¹³

We build our instrumental variable in three steps. The first part of our IV concerns the returns for LPs. For this we use the nationwide annual university endowment returns from the National Association of College and University Business Officers (NACUBO). Next, for each MSA region we count the number of LPs that invested in venture capital at least 10 years prior to the year of interest; given this time lag the investment pattern of LPs should be unaffected by the local investment conditions. To account for the tendency of LPs to invest in local VC funds, we weight the instrumental variable by the distance between an MSA region and the market of interest. Lastly, we include the share of VC investments made in the focal industry in an MSA region, considering all deals that took place at least 10 years before the year of interest.

¹³We compute the percentages of funding rounds for companies in each industry group, relative to all funding rounds in a given location in each year. The coefficients of variation for the industry distributions of VC deals ranges from 0.118 and 1.039, with a median of 0.464.

Using a 10-year lag we ensure that variations are not caused by recent changes in investment opportunities within a particular industry.

We denote by LPR_{ist} the instrument for competitive supply of venture capital in region (or state) s , industry i , and year t , which is defined by

$$LPR_{ist} = Indshare_{ist} \sum_j \sum_{h=t-4}^{t-6} \frac{ER_h \ln(1 + LP_{jh})}{1 + dist_{sj}}, \quad (3.1)$$

where ER_h is the nationwide average university endowment return in year h , and LP_{jh} is a counter of the distinct LPs in region j that invested in VC funds at least 10 years prior to year h . Moreover, $dist_{sj}$ represents the distance between the centroid of region s and the centroid of region j , and $Indshare_{ist}$ is the ratio of the number of VC investments at least 10 years prior to time t in industry i and region s , and the number of all VC investments in region s . Because it takes time for LPs to allocate capital across different asset classes, the measure is cumulated for three years of lagged returns. And the distance weight takes into account that LPs tend to invest in VC funds located nearby.

The relevance of the instrumental variable depends in general on how the investment return for LPs affects competition in the VC market. As LPs realize higher returns and invest more in venture capital, concentration in local VC markets may increase or decrease, depending on how the additional capital is allocated across VC firms. If only a small number of VC firms benefit from the additional capital from LPs, then each has more resources to fund companies, leading to a more concentrated market structure. On the other hand, if a large number of VC firms obtain additional capital from LPs, then competition in local VC markets intensifies. We examine the investment activities of two types of investors to establish the relevance of our instrument: dominant incumbents and entrants. For a given market and year, we define entrants as VC firms that invest in the market for the first time (Hochberg et al., 2007). Moreover, we consider a VC firm as a dominant incumbent VC firm when it belongs to the group of VC firms with a combined market share of 80 percent as measured over the prior 5-year window. Column 1 of Table 2 shows that higher investment returns for LPs are associated with a larger number of deals. Furthermore, the increase in deals seems to be driven by entrants investing in startup companies: Columns 3 and 5 of Table 2 show that entrant VC firms finance more deals (in absolute and relative terms) following a higher investment return for LPs. In contrast, Columns 2 and 4 of Table 2 indicate that dominant incumbent VC firms finance fewer deals (in absolute and relative terms) after LPs realize higher returns on their investments. We also examine the fund raising activities of entrant and dominant VC firms, and find that following

higher investment returns for LPs, only entrants are able to raise more funds. We note that the investment return for LPs positively affects the funds raised by dominant VC firms; however this effect is not statistically significant, and far less pronounced than the effect on the entrants. All these suggest that LPs, after realizing higher investment returns, increase their investments in funds managed by newly entering VC firms. And this can potentially lead to more concentrated markets given the relatively small number of entrants in a given market and year.¹⁴ Finally we note that variations in the returns of LPs are unlikely to be driven by VC fund performance. This is because venture capital typically represents a small share of an LP's investment portfolio.¹⁵

We use the following specification to test for the effect of market concentration on pre-money valuations of startup companies:

$$\begin{aligned} \text{Log}(\text{Pre-money Valuations}_{ijmt}) = & \alpha + \beta_1 \text{Concentration}_{mt} + \beta_2 C_{imt} + \beta_3 X_{jmt} \\ & + \beta_4 M_{mt} + \phi_m + \tau_t + \epsilon_{ijmt}, \end{aligned} \quad (3.2)$$

where i , j , m , and t index the portfolio company, VC firm, market, and year, respectively. The dependent variable, $\text{Log}(\text{Pre-money Valuations})$, is the logged pre-money valuation of a portfolio company in the first funding round.

The key independent variable is *Concentration*, which measures the concentration of VC market at the market level. As explained above, we use two alternative measures of market concentration: (i) the Herfindahl-Hirschman Index (HHI) based on the number of VC firms investing in a given market and year, and (ii) the inverse number of investing VC firms in a given market and year. Moreover, C_{imt} represents a set of control variables for the characteristics of portfolio companies, including (i) the logged value of the age of a portfolio company, (ii) company development stage dummies (i.e., seed, early stage, later stage, expansion), and (iii), the logged number of participating investors in the current round. In addition, X_{jmt} refers to a set of controls for the characteristics of the lead investor in the current round, which include the logged number of prior funding rounds, and the logged value of its fund size. Finally, M_{mt} is a set of market characteristics, including (i) the logged value of capital raised by all VC funds in the previous four quarters, and (ii) the book-to-market ratio of the public companies in the same industry as the portfolio companies.

¹⁴On average 27 VC firms invest in startup companies in a given market-year, and only 10 of these are entrants.

¹⁵In fact, according to the Educational Endowments Report published by NACUBO in 2015, university endowments invest on average only 5 percent in venture capital.

3.3.2 Main Results

Table 3 shows the regression results concerning the effect of market concentration on pre-money valuations. Columns 1 and 2 report the OLS results for our two alternative concentration measures. Columns 3 and 4 present the 2SLS results. When comparing the estimation results using OLS and 2SLS, we can infer that failing to control for omitted variables results in an upward bias in the estimate of the effect of market concentration. This suggests that the omitted variables simultaneously make markets more concentrated and lead to higher valuations of portfolio companies. One plausible example of such an omitted variable is the profitability of the entrepreneurial project. On the one hand, projects with higher commercial potential receive higher valuations from investors. On the other hand, this may encourage a small number of VC firms to increase their investments aimed at strengthening their positions in the market.

The IV results indicate that market concentration is negatively related to company valuations, and this effect is statistically significant. Holding all other things constant, pre-money valuations decrease by 6.7 percent when the number of investing VC firms in a given market decreases from 10 to 9. Furthermore, in case all investing VC firms split the total investment amount in a given round equally, the same change in the number of investing VC firms causes the HHI to increase by 0.011, and this leads to 7.7 percent lower valuation of startup companies.

It is important to note that the Thomson One valuation data is subject to a selection bias. More specifically, the sample contains only information on pre-money valuations for about one-fifth of all deals. And previous literature suggests that companies may strategically disclose information about valuation (see, e.g., Hochberg et al. (2007), and Hwang et al. (2005)). We correct for the potential bias from both sample selection and endogenous variables as follows (see Wooldridge (2010)): We first use a selection equation to estimate the inverse Mills ratios. We then estimate the structural model using 2SLS, and include the estimated inverse Mills ratios as an independent variable. We also correct for the generated regressors problem by using bootstrap standard errors.

To estimate the inverse Mills ratios we use a selection equation as proposed by Hwang et al. (2005); we provide more details in Section A.7 in the Appendix. We estimate an ordered probit model that examines seven possible investment outcomes for a VC-backed company in each quarter. The seven possible outcomes are ordered from the least desirable to the most desirable outcome: (i) shutdown, (ii) acquisition without disclosure of company valuation, (iii) no funding at all, (iv) funding without disclosure of company valuation, (v) funding with disclosure of company valuation, (vi) acquisition with disclosure of company valuation, and (vii), IPO. The explanatory variables include company 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 then include the inverse Mills ratios when estimating (3.2) using 2SLS.

Columns 5 and 6 in Table 3 report the regression results. After controlling for sample selection and endogeneity, we continue to observe a negative and statistically significant effect of market concentration on pre-money valuations. The magnitudes of the estimated coefficients for the concentration measures are slightly higher compared to those generated by 2SLS. Moreover, the inverse Mills ratios have a significant effect on pre-money valuations, indicating the presence of a sample selection bias if one does not correct for it.

3.4 The Effects of Concentration on Portfolio Company Performance

Our theory also predicts differential effects of market concentration on the performance of portfolio companies. Specifically, a higher market concentration (i.e., less competition) improves the success rate of startup companies backed by more experienced VC firms, while it reduces the success rate of startups backed by less experienced VC firms (Hypothesis 2).

To empirically investigate these differential effects, we compute the median experience of VC firms in each market and year, as measured by the number of previous funding rounds a VC firm participated in. We then divide the sample into two groups: companies backed by VC firms with experience higher than the median level in a given market, and VC firms with experience less than the median level. For each group we estimate the effect of concentration on the performance of portfolio companies using the following specification:

$$\begin{aligned}
 IPO_{ijmt} = & \alpha + \beta_1 Concentration_{mt} + \beta_2 C_{imt} + \beta_3 X_{jmt} + \beta_4 M_{mt} \\
 & + \phi_m + \tau_t + \epsilon_{ijmt},
 \end{aligned} \tag{3.3}$$

where i , j , m , and t index the portfolio company, VC firm, market, and year, respectively. The dependent variable, IPO_{ijmt} , is binary, and indicates if a company had an IPO exit. We relate a company's chance to undergo an IPO to the following variables: the characteristics of the lead investor (including fund size and experience), the characteristics of portfolio companies (such as age and development stage), the book-to-market ratio of the public companies in the same industry as the portfolio companies, the total inflow of capital into VC funds in the prior four quarters, the number of investors as well as investment amounts received in the first funding

round, and our measures of market concentration. We use a linear probability model (LPM) to fit the data, and include market and year fixed effects.

We note that the estimation of (3.3) is subject to endogeneity concerns. Unobservables about portfolio companies may correlate with market concentration, and, at the same time, may affect companies' likelihoods of going public, leading to an omitted variable bias. We use the same instrumental variable as described in Section 3.3.1 to address this potential endogeneity problem. Table 2 indicates that the investment returns of university endowments are related to the concentration of VC markets. The exclusion condition from Section 3.3.1 also holds: the investment returns of university endowments are uncorrelated with unobservables about portfolio companies.

Tables 4 and 5 report the estimation results for portfolio companies backed by inexperienced and experienced VC firms, respectively. Columns 1 and 3 of Table 4 report the results from OLS estimation, showing a negative but statistically insignificant relationship between market concentration and the likelihood of going public for companies backed by inexperienced VC firms. Columns 2 and 4 show the estimation results from 2SLS: both market concentration measures have a negative and statistically significant effect on the likelihood of an IPO for companies backed by inexperienced VC firms. Comparing Columns 1 and 3 with the other columns suggests that failing to control for omitted variables results in an upward bias in the estimate of the effect of market concentration. One plausible example of such omitted variable is the productivity of start-ups in a given market, which is associated with higher IPO rates, and at the same time, leads to more concentrated market. Moreover, we can see from Column 3 that the likelihood of an IPO decreases by 2.8 percent when the number of VC firms decreases from 10 to 9 in a given market.

Table 5 reports the estimation results for portfolio companies backed by experienced VC firms. The OLS estimation leads to mixed results: Column 1 shows a positive correlation between the HHI and the likelihood for a portfolio company to have an IPO, whereas Column 3 indicates a negative relationship between the inverse number of VC firms and the IPO rate of portfolio companies. However, once we control for endogeneity of market concentration (see Columns 2 and 4), we find again that market concentration has a positive and significant effect on the IPO rate of portfolio companies.

When comparing the OLS results with the 2SLS estimates in Table 5, we can infer that the omitted variables are negatively correlated with market concentration. One plausible example of such an omitted variable is the innovativeness of portfolio companies. Nanda and Rhodes-Kropf (2013) find that VC-backed companies are more experimental when receiving their initial investment in hot markets. This implies a higher chance of failure, but conditional on going

public, those more experimental companies receive a higher valuation on the day of their IPO. Furthermore, this observation is also driven by more experienced VC firms investing in more experimental startup companies in hot markets, compared to less experienced VC firms. Overall we note that this is consistent with our estimation results in Table 5. We have shown in Section 3.3.1 that a higher inflow of capital into the VC market leads to a more concentrated VC market. And then more experienced VC firms tend to fund more experimental projects. As a result, the unobservables (such as the innovativeness of entrepreneurial projects) have a negative effect on the IPO rates. Compared to the 2SLS estimates, this implies a negative bias of the OLS estimation of the effect of market concentration on IPO rates of portfolio companies backed by more experienced VC firms.

4 Conclusion

In this paper we examine how competition in the market for venture capital affects the valuation of startup companies, and their likelihood to experience a successful exit (IPO). We first develop and analyze a matching model of the VC market with two-sided heterogeneity and double-sided moral hazard. The model shows that competition has a differential effect, which depends on the actual quality of entrepreneurial projects and the experience of investors: ventures with lower quality projects (backed by less experienced VC firms) experience higher success rates, while ventures with higher quality projects (backed by more experienced VC firms) experience lower success rates, in more competitive VC markets. In contrast, the model shows that competition has a positive effect on the valuation of all new ventures (with low and high quality projects alike). We then provide empirical support for our predictions using VC investment data from Thomson One.

We believe that our key insights are important for the following main reasons. First, they help us to better understand the link between competition in the market for venture capital, and the success of innovative ventures. Second, our insights can have important policy ramifications: Any policy that enhances the supply of venture capital (such as investor tax credits), will lead to more innovative projects to be funded. This, however, comes at a cost: it deteriorates the likelihood for the most innovative ventures to experience a successful exit, while it improves the funding and survival rates of new ventures with marginal projects. It is therefore not immediately clear whether there is a role for the government to spur VC investments to ensure that more startup companies receive funding. We note, however, that our research focuses on the effects on valuations and exits, but there are clearly other important aspects to consider for

policy makers when designing policies to foster startup funding. Overall we believe that this provides an interesting an important avenue for future research.

A Appendix

A.1 Effort levels and success probability

Consider the entrepreneur's expected utility U^E . We get the following first-order condition which defines EN's effort level e : $e = \phi e^{\phi-1} v^{1-\phi} (1-s) \pi$. Solving for e we get

$$e = v^{\frac{1-\phi}{2-\phi}} [\phi (1-s) \pi]^{\frac{1}{2-\phi}}. \quad (\text{A.1})$$

Now consider the VC firm's expected utility U^V . The first-order condition, which defines the VC firm's effort level, is given by $v = (1-\phi) e^\phi v^{-\phi} s \pi$. Solving for v ,

$$v = e^{\frac{\phi}{1+\phi}} [(1-\phi) s \pi]^{\frac{1}{1+\phi}}. \quad (\text{A.2})$$

Substituting (A.2) in (A.1) we get

$$e = e^{\frac{\phi(1-\phi)}{(1+\phi)(2-\phi)}} [(1-\phi) s \pi]^{\frac{1-\phi}{(1+\phi)(2-\phi)}} [\phi (1-s) \pi]^{\frac{1}{2-\phi}}.$$

Solving for e and simplifying,

$$\begin{aligned} e^{1-\frac{\phi(1-\phi)}{(1+\phi)(2-\phi)}} &= [(1-\phi) s \pi]^{\frac{1-\phi}{(1+\phi)(2-\phi)}} [\phi (1-s) \pi]^{\frac{1}{2-\phi}} \\ \Leftrightarrow e^{\frac{2}{(1+\phi)(2-\phi)}} &= [(1-\phi) s \pi]^{\frac{1-\phi}{(1+\phi)(2-\phi)}} [\phi (1-s) \pi]^{\frac{1}{2-\phi}} \\ \Leftrightarrow e &= \left[[(1-\phi) s \pi]^{\frac{1-\phi}{(1+\phi)(2-\phi)}} [\phi (1-s) \pi]^{\frac{1}{2-\phi}} \right]^{\frac{(1+\phi)(2-\phi)}{2}}. \end{aligned}$$

Consequently,

$$e(s) = [(1-\phi) s]^{\frac{1-\phi}{2}} [\phi (1-s)]^{\frac{(1+\phi)}{2}} \pi. \quad (\text{A.3})$$

Likewise, substituting (A.1) in (A.2) we get

$$\begin{aligned} v &= \left[v^{\frac{1-\phi}{2-\phi}} [\phi (1-s) \pi]^{\frac{1}{2-\phi}} \right]^{\frac{\phi}{1+\phi}} [(1-\phi) s \pi]^{\frac{1}{1+\phi}} \\ \Leftrightarrow v^{1-\frac{(1-\phi)\phi}{(2-\phi)(1+\phi)}} &= [\phi (1-s)]^{\frac{1}{2-\phi} \frac{\phi}{1+\phi}} [(1-\phi) s]^{\frac{1}{1+\phi}} \pi^{\frac{1}{2-\phi} \frac{\phi}{1+\phi} + \frac{1}{1+\phi}} \\ \Leftrightarrow v^{\frac{2}{(2-\phi)(1+\phi)}} &= [\phi (1-s)]^{\frac{1}{2-\phi} \frac{\phi}{1+\phi}} [(1-\phi) s]^{\frac{1}{1+\phi}} \pi^{\frac{2}{(2-\phi)(1+\phi)}}. \end{aligned}$$

Therefore,

$$v(s) = [\phi(1-s)]^{\frac{\phi}{2}} [(1-\phi)s]^{\frac{2-\phi}{2}} \pi. \quad (\text{A.4})$$

Finally, substituting (A.3) and (A.4) in the success probability $\rho = e_i^\phi v_j^{1-\phi}$ we get

$$\begin{aligned} \rho(s) &= \left[[(1-\phi)s]^{\frac{1-\phi}{2}} [\phi(1-s)]^{\frac{(1+\phi)}{2}} \pi \right]^\phi \left[[\phi(1-s)]^{\frac{\phi}{2}} [(1-\phi)s]^{\frac{2-\phi}{2}} \pi \right]^{1-\phi} \\ &= [(1-\phi)s]^{\frac{(1-\phi)\phi}{2} + \frac{(2-\phi)(1-\phi)}{2}} [\phi(1-s)]^{\frac{(1+\phi)\phi}{2} + \frac{(1-\phi)\phi}{2}} \pi \\ &= [(1-\phi)s]^{1-\phi} [\phi(1-s)]^\phi \pi. \end{aligned}$$

A.2 Proof of Lemma 1

Substituting $e(s)$, $v(s)$, and $\rho(s)$ in the EN's expected utility U^E we get

$$\begin{aligned} U^E(s) &= [(1-\phi)s]^{1-\phi} [\phi(1-s)]^\phi \pi (1-s) \pi - \frac{1}{2} [(1-\phi)s]^{1-\phi} [\phi(1-s)]^{(1+\phi)} \pi^2 \\ &= \left[\phi^\phi (1-s)^{1+\phi} - \frac{1}{2} \phi \phi^\phi (1-s)^{1+\phi} \right] [(1-\phi)s]^{1-\phi} \pi^2 \\ &= \left[\frac{2-\phi}{2\phi} \right] [\phi(1-s)]^{1+\phi} [(1-\phi)s]^{1-\phi} \pi^2. \end{aligned}$$

The EN's preferred sharing rule, denoted s^E , is defined by the first-order condition:

$$\left[\frac{2-\phi}{2\phi} \right] \pi^2 \left[-\phi(1+\phi) [\phi(1-s)]^\phi [(1-\phi)s]^{1-\phi} + (1-\phi)^2 [\phi(1-s)]^{1+\phi} [(1-\phi)s]^{-\phi} \right] = 0.$$

Solving for s ,

$$(1-\phi)^2 \phi (1-s) = \phi(1+\phi) [(1-\phi)s] \quad \Leftrightarrow \quad s^E = \frac{1}{2} (1-\phi).$$

Likewise, using $e(s)$, $v(s)$, and $\rho(s)$, we can write the VC firm's expected utility U^V as

$$\begin{aligned}
U^V(s) &= [(1-\phi)s]^{1-\phi} [\phi(1-s)]^\phi \pi s \pi - \frac{1}{2} [\phi(1-s)]^\phi [(1-\phi)s]^{2-\phi} \pi^2 \\
&= \left[(1-\phi)^{-1} - \frac{1}{2} \right] [(1-\phi)s]^{2-\phi} [\phi(1-s)]^\phi \pi^2 \\
&= \frac{1+\phi}{2(1-\phi)} [(1-\phi)s]^{2-\phi} [\phi(1-s)]^\phi \pi^2. \tag{A.5}
\end{aligned}$$

Let s^V denote the sharing rule preferred by the VC firms, which is defined by the first-order condition:

$$\frac{1+\phi}{2(1-\phi)} \pi^2 \left[(2-\phi)(1-\phi) [(1-\phi)s]^{1-\phi} [\phi(1-s)]^\phi - \phi^2 [(1-\phi)s]^{2-\phi} [\phi(1-s)]^{\phi-1} \right] = 0.$$

Solving for s ,

$$(2-\phi)(1-\phi)\phi(1-s) = \phi^2(1-\phi)s \quad \Leftrightarrow \quad s^V = \frac{1}{2}(2-\phi).$$

Next, note that the joint utility is given by $U^E(s) + U^V(s) = \rho(s)\pi - [e(s)]^2/2 - [v(s)]^2/2$. Using the expressions for $\rho(s)$, $e(s)$, and $v(s)$, we get

$$\begin{aligned}
U^E(s) + U^V(s) &= [(1-\phi)s]^{1-\phi} [\phi(1-s)]^\phi \pi^2 \\
&\quad - \frac{1}{2} \left[[(1-\phi)s]^{1-\phi} [\phi(1-s)]^{(1+\phi)} \pi^2 - [\phi(1-s)]^\phi [(1-\phi)s]^{2-\phi} \pi^2 \right] \\
&= [(1-\phi)s]^{1-\phi} [\phi(1-s)]^\phi \pi^2 - \frac{1}{2} [(1-\phi)s]^{1-\phi} [\phi(1-s)]^\phi \pi^2 [\phi - \phi s - 1 + \phi s] \\
&= \frac{1}{2} [3-\phi] [(1-\phi)s]^{1-\phi} [\phi(1-s)]^\phi \pi^2.
\end{aligned}$$

The Pareto efficient sharing rule, denoted by s^J , is defined the first-order condition:

$$\frac{1}{2} [3-\phi] \pi^2 \left[(1-\phi)^2 [(1-\phi)s]^{-\phi} [\phi(1-s)]^\phi - \phi^2 [(1-\phi)s]^{1-\phi} [\phi(1-s)]^{\phi-1} \right] = 0.$$

Solving for s :

$$(1-\phi)^2 [\phi(1-s)] = \phi^2 [(1-\phi)s] \quad \Leftrightarrow \quad s^J = 1-\phi.$$

Likewise, the sharing rule which maximizes the success probability $\rho(s)$, is given by the corresponding first-order condition:

$$(1 - \phi)^2 [(1 - \phi) s]^{-\phi} [\phi (1 - s)]^\phi - \phi^2 [(1 - \phi) s]^{1-\phi} [\phi (1 - s)]^{\phi-1} = 0.$$

Solving for s ,

$$(1 - \phi)^2 \phi (1 - s) = \phi^2 (1 - \phi) s \quad \Leftrightarrow \quad s = 1 - \phi.$$

Thus, $\rho(s)$ is maximized for $s = s^J = 1 - \phi$.

Finally, it is easy to see that $s^E < s^J < s^V$. □

A.3 Proof of Lemma 2

Using the expressions for $U^V(s)$ and $U^E(s)$ we get the following maximization problem for the VC firm:

$$\max_{s \in [s^E, s^V]} U^V(s) = \frac{1 + \phi}{2(1 - \phi)} [(1 - \phi) s]^{2-\phi} [\phi (1 - s)]^\phi \pi^2$$

s.t.

$$U^E(s) = \left[\frac{2 - \phi}{2\phi} \right] [\phi (1 - s)]^{1+\phi} [(1 - \phi) s]^{1-\phi} \pi^2 \geq u. \quad (\text{A.6})$$

Note that $U^E(s = s^V) > 0$. Thus, the EN's participation constraint (A.6) with $s = s^V$ is satisfied (and non-binding) for a sufficiently low u . Let u' denote the reservation utility so that (A.6) is binding for $s = s^V$, i.e., $U^E(s = s^V) = u'$. Thus, for $u \leq u'$ the equilibrium sharing rule is $s^*(u) = s^V$. For $u > u'$ the sharing rule $s = s^V$ would violate (A.6). Consequently, the VC firm chooses the sharing rule $s^*(u)$ which satisfies the binding participation constraint $U^E(s) = u$. Using the binding participation constraint $U^E(s) = u$ we can implicitly differentiate $s^*(u)$ w.r.t. u :

$$\frac{ds^*(u)}{du} = - \frac{1}{\left[\frac{2-\phi}{2\phi} \right] \pi^2 \left[\phi (1 + \phi) [\phi (1 - s)]^\phi [(1 - \phi) s]^{1-\phi} + \phi (1 - \phi) [\phi (1 - s)]^{1+\phi} [(1 - \phi) s]^{-\phi} \right]} < 0.$$

□

A.4 Indifference curve of a VC firm

The slope of VC firm j 's indifference curve, when being matched with EN i , is given by

$$\Psi(i, j) = -\frac{\frac{dU^V(i, j, u)}{di}}{\frac{dU^V(i, j, u)}{du}} = -\frac{U_s^V \frac{ds^*}{di} + U_i^V}{U_s^V \frac{ds^*}{du}}.$$

Using EN i 's binding participation constraint (A.6) (see Proof of Lemma 2), we get

$$\begin{aligned} \frac{ds^*}{di} &= -\frac{2\pi\pi_i \left[\frac{2-\phi}{2\phi}\right] [\phi(1-s)]^{1+\phi} [(1-\phi)s]^{1-\phi}}{\left[\frac{2-\phi}{2\phi}\right] \pi^2 \left[-\phi(1+\phi) [\phi(1-s)]^\phi [(1-\phi)s]^{1-\phi} + (1-\phi)^2 [\phi(1-s)]^{1+\phi} [(1-\phi)s]^{-\phi}\right]} \\ &= -\frac{2\pi_i}{\pi \left[-\phi(1+\phi) [\phi(1-s)]^{-1} + (1-\phi)^2 [(1-\phi)s]^{-1}\right]} = -2\frac{\pi_i}{\pi} \frac{s(1-s)}{1-2s-\phi}. \end{aligned}$$

Likewise,

$$\begin{aligned} \frac{ds^*}{du} &= \frac{1}{\left[\frac{2-\phi}{2\phi}\right] \pi^2 \left[-\phi(1+\phi) [\phi(1-s)]^\phi [(1-\phi)s]^{1-\phi} + (1-\phi)^2 [\phi(1-s)]^{1+\phi} [(1-\phi)s]^{-\phi}\right]} \\ &= \frac{s(1-s)}{\left[\frac{2-\phi}{2\phi}\right] \pi^2 [\phi(1-s)]^{1+\phi} [(1-\phi)s]^{1-\phi} [1-2s-\phi]}. \end{aligned} \tag{A.7}$$

Moreover, using (A.5), we get

$$\begin{aligned} U_s^V &= \frac{1+\phi}{2(1-\phi)} \pi^2 \left[(1-\phi)(2-\phi) [(1-\phi)s]^{1-\phi} [\phi(1-s)]^\phi - \phi^2 [(1-\phi)s]^{2-\phi} [\phi(1-s)]^{\phi-1} \right] \\ &= \frac{1+\phi}{2(1-\phi)} \pi^2 [(1-\phi)s]^{2-\phi} [\phi(1-s)]^\phi \left[\frac{2-2s-\phi}{s(1-s)} \right] \\ U_i^V &= 2\pi\pi_i \frac{1+\phi}{2(1-\phi)} [(1-\phi)s]^{2-\phi} [\phi(1-s)]^\phi. \end{aligned}$$

Thus, the slope of VC firm j 's indifference curve is given by

$$\begin{aligned}
\Psi(i, j) &= -\frac{\pi \left[\frac{2-2s-\phi}{s(1-s)} \right] \frac{ds^*}{di} + 2\pi_i}{\pi \left[\frac{2-2s-\phi}{s(1-s)} \right] \frac{ds^*}{du}} \\
&= -\frac{2\pi_i \left[1 - \left[\frac{2-2s-\phi}{1-2s-\phi} \right] \right] \left[\frac{2-\phi}{2\phi} \right] \pi^2 [\phi(1-s)]^{1+\phi} [(1-\phi)s]^{1-\phi} [1-2s-\phi]}{\pi [2-2s-\phi]} \\
&= 2\frac{\pi_i}{\pi} \frac{1}{2-2s-\phi} \underbrace{\left[\frac{2-\phi}{2\phi} \right] [\phi(1-s)]^{1+\phi} [(1-\phi)s]^{1-\phi} \pi^2}_{=U^E(s,i,j)}.
\end{aligned}$$

According to EN i 's binding participation constraint (A.6), $U^E(s, i, j) = u(i)$. Thus,

$$\Psi(i, j) = 2\frac{\pi_i}{\pi} \frac{1}{2-2s-\phi} u.$$

Next we need to show that $\Psi(i, j)$ is increasing in j . For this we first note that $u(i)$ is constant in j . Moreover, using EN i 's binding participation constraint (A.6) we get

$$\begin{aligned}
\frac{ds^*}{dj} &= -\frac{2 \left[\frac{2-\phi}{2\phi} \right] \pi \pi_j [\phi(1-s)]^{1+\phi} [(1-\phi)s]^{1-\phi}}{\left[\frac{2-\phi}{2\phi} \right] \pi^2 \left[-\phi(1+\phi) [\phi(1-s)]^\phi [(1-\phi)s]^{1-\phi} + (1-\phi)^2 [\phi(1-s)]^{1+\phi} [(1-\phi)s]^{-\phi} \right]} \\
&= -2\frac{\pi_j}{\pi} \frac{1}{\left[-\phi(1+\phi) [\phi(1-s)]^{-1} + (1-\phi)^2 [(1-\phi)s]^{-1} \right]} = 2\frac{\pi_j}{\pi} \frac{s(1-s)}{2s+\phi-1},
\end{aligned}$$

which is strictly positive for $s^* > s^E = \frac{1}{2}(1-\phi)$. Consequently,

$$\begin{aligned}
\frac{d\Psi(i, j)}{dj} &= 2u \frac{\pi_{ij}\pi(2-2s-\phi) - \pi_i \left[\pi_j(2-2s-\phi) - 2\pi \frac{ds^*}{dj} \right]}{[\pi(2-2s-\phi)]^2} \\
&= 2u \frac{\pi_{ij}\pi(2-2s-\phi) + \pi_i \pi_j \overbrace{\left[4\frac{s(1-s)}{2s+\phi-1} - (2-2s-\phi) \right]}{=Z}}{[\pi(2-2s-\phi)]^2}.
\end{aligned}$$

This is positive if $Z > 0$ (which is a sufficient condition, as by assumption $\pi_{ij} \geq 0$). Recall from Lemma 1 that $s^* \in (s^E, s^V) = \left(\frac{1}{2}(1-\phi), \frac{1}{2}(2-\phi) \right)$. We can thus write $s^*(\eta) =$

$\frac{1}{2}(1 + \eta - \phi)$, with $\eta \in (0, 1)$. It is then sufficient to show that $Z > 0$ for all $\eta \in (0, 1)$. Using $s^*(\eta)$ we can write $T > 0$ as

$$\begin{aligned} \frac{2(1 + \eta - \phi)\left(1 - \frac{1}{2}(1 + \eta - \phi)\right)}{(1 + \eta - \phi) + \phi - 1} &> 2 - (1 + \eta - \phi) - \phi \\ \Leftrightarrow (1 + \eta - \phi)(1 - \eta + \phi) &> (1 - \eta)\eta \\ \Leftrightarrow 1 - \phi^2 + 2\eta\left(\phi - \frac{1}{2}\right) &> 0, \end{aligned}$$

which is clearly satisfied for $\phi \in [\frac{1}{2}, 1)$. Consequently, $d\Psi(i, j)/dj > 0$.

A.5 Existence of a unique solution to the ODE (2.5)

We assume that the Picard-Lindelöf Theorem holds, and therefore a unique solution to (2.5) exists, at least in the neighborhood of the initial condition. We need $dU^E(i)/di$ to be Lipschitz continuous in U^E and continuous in i , see Birkoff and Rota (1989). Our assumptions ensure that $dU^E(i)/di$ is continuous in i (note that i enters through π , which we assume is continuously differentiable in its arguments). If a differentiable function has a derivative that is bounded everywhere by a real number, then the function is Lipschitz continuous. The derivative of (2.5) with respect to U^E , or u , is

$$\frac{\pi_i}{\pi} \left(\frac{2}{2 - 2s - \phi} + \frac{4u \frac{ds}{du}}{(2 - 2s - \phi)^2} \right).$$

The above is bounded by a real number provided that $s < s^V \equiv \frac{1}{2}(2 - \phi)$ and $\frac{ds}{du}$ is bounded. The former holds since we have assumed that the initial condition \underline{u} , is higher than the utility the EN would get when $s = s^V$ and so $s < s^V$ and the latter holds as long as $s > s^E \equiv \frac{1-\phi}{2}$ (see (A.7)), which we assume it holds (in other words the highest quality EN-VC pair in the market offers less equity than the one that maximizes the EN's utility).

A.6 Model with transfer payments

In our main text we focus on simple equity sharing contracts between ENs and VC firms to keep the model as simple and transparent as possible. We therefore implicitly assumed that no party can make a monetary transfer payment to buy additional equity from the other party. This is intuitive for entrepreneurs who are typically wealth constrained (which is a reason why they need

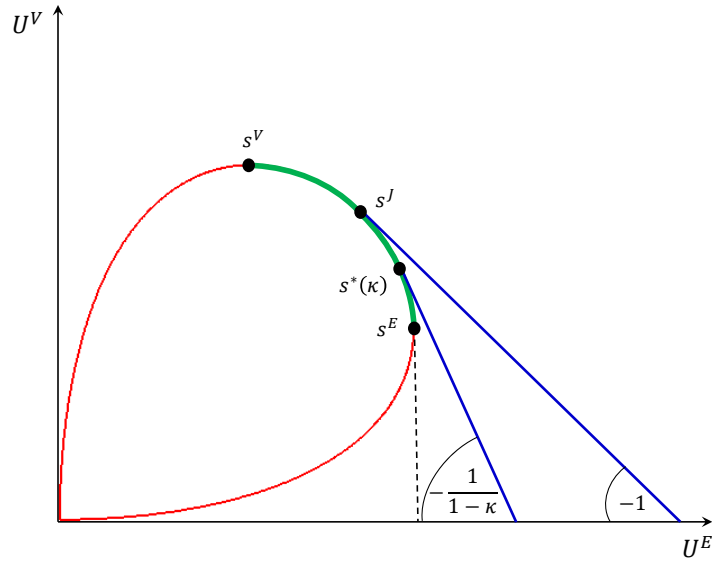


Figure 4: Utility-possibility frontier with transfer payments

VC in the first place). However, VC firms may have some cash beyond the required investment amount K which they could use to buy some additional equity from their entrepreneurs (see, e.g., Hellmann (2006) and Jovanovic and Szentes (2012)). We now briefly show that allowing VC firms to make such transfer payments does not change the qualitative nature of our main results, as long as transfers are costly.

We first note that it can only be optimal for the VC firm to make a transfer payment, and for the EN to accept this payment, when it leads to a Pareto improvement. This is clearly the case when the VC firm gets too little equity from a joint perspective, i.e., $s^* \in [s^E, s^J]$; see Figure 4. And we know from our analysis that this requires the EN's outside option u to be sufficiently high, which applies when the entrepreneur has a high quality project and receives funding from a high experience VC firm. For the remainder of this section we focus on this case.

Suppose the VC firm can transfer the amount T to the entrepreneur at a cost κT , with $\kappa \in [0, 1]$, to buy some additional equity. We can see from Figure 4 how costly transfer payments affect the utility-possibility frontier (UPF) between the VC firm and the entrepreneur. Specifically, the VC firm can get a higher expected utility by increasing its equity share to some $s^*(\kappa) \in (s^E, s^J]$, where the marginal rate of substitution satisfies $dU^V/dU^E = -1/(1 - \kappa)$. Buying even more equity would be inefficient for the VC firm, as the additionally required transfer would exceed the extra utility from getting a higher equity stake.

When $\kappa = 1$ we are back to our base model, where utility can only be transferred through the sharing rule s . With $\kappa = 0$ we have perfectly transferable utility up to the point s^J on the UPF, as reflected by the blue line at point s^J with a slope of negative one; see Figure 4. In this case it would always be efficient for the VC firm to buy enough additional equity from the

EN so that $s^* = s^J$. Consequently, VC competition would then not change the outcome (i.e., valuation and probability of success) for high quality projects backed by high experience VC firms.

The most important insight is that for any $\kappa \in (0, 1)$, the maximum equity share that the VC firm can get, is somewhere between s^E and s^J . In Figure 4 this is reflected by the point $s^*(\kappa)$ on the UPF (which has the slope $-1/(1 - \kappa)$). This implies that even monetary transfer payments cannot achieve the Pareto efficient outcome (s^J), as long as there is some cost $\kappa > 0$ to making such transfers. It would then still be true that stronger VC competition leads to lower valuations and success probabilities of high quality projects funded by high experience VC firms.

Finally, we note that our empirical results indicate that transaction costs may play a role in VC contracting (otherwise competition would not affect the valuation and success rate of high quality projects). Overall this suggests that the Pareto efficient outcome is often not achieved, so that the likelihood of startup companies to succeed is inefficiently low.

A.7 Sample selection with endogenous explanatory variables

We now establish the sample selection model when one of the explanatory variables is endogenous (see Hwang et al. (2005)). The structural equation takes the following form:

$$y_{1it} = z_{1it}\delta_1 + y_{2it}\alpha_1 + u_{1it},$$

where y_{2it} is subject to endogeneity concerns. Moreover, we can identify y_{2it} using $y_{2it} = z_{2it}\delta_2 + v_{2it}$.

The selection equation is built around the following latent regression: $I_{it}^* = z_{it}\delta_3 + v_{3it}$. Using the seven possible events as described in Section 3.3.2, we define I_{it} as follows:

$$I_{it} = \begin{cases} \text{Event 1 if } I_{it}^* \leq \tau_1 \\ \text{Event } j \text{ if } \tau_{j-1} < I_{it}^* \leq \tau_j \text{ for } 2 \leq j \leq 6 \\ \text{Event 7 if } I_{it}^* > \tau_6. \end{cases}$$

Furthermore, we make the following assumptions: (i) (z_{it}, I_{it}) is always observed, and the observation of y_{1it} is dependent on I_{it} , (ii) $v_{3it} \sim N(0, 1)$, (iii) $E(u_{1it}|v_{3it}) = \gamma_1 v_{3it}$, and (iv) $E(z'_{2it}v_{2it}) = 0$. Given these assumptions we can write y_{1it} as $y_{1it} = z_{1it}\delta_1 + y_{2it}\alpha_1 + E(u_{1it}|z_{it}, I_{it}) + e_{1it}$, with $e_{1it} \equiv u_{1it} - E(u_{1it}|z_{it}, I_{it})$. By definition, $E(e_{1it}|z_{it}, I_{it}) = 0$. Moreover, $z_{2it}\delta_2 = z_{1it}\delta_{21} + z_{21it}\delta_{22}$, $\delta_{22} \neq 0$. For parsimony we suppress the subscript it whenever possible.

Given the selection equation we need to consider the following three cases.

Case 1: y_1 is observed only when $I_{it}^* > a$, so that

$$\begin{aligned} E(y_1 | \mathbf{z}_1, \mathbf{z}_3, I_{it}^* > a) &= \mathbf{z}_1 \delta_1 + \alpha_1 y_2 + E(u_1 | \mathbf{z}_3, I_{it}^* > a) \\ &= \mathbf{z}_1 \delta_1 + \alpha_1 y_2 + \gamma_3 \frac{\phi(a - \mathbf{z}_3 \delta_3)}{\Phi(-(a - \mathbf{z}_3 \delta_3))}. \end{aligned}$$

The Mills ratio is the given by $\frac{\phi(a - \mathbf{z}_3 \delta_3)}{\Phi(-(a - \mathbf{z}_3 \delta_3))}$.

Case 2: y_1 is observed only when $I_{it}^* \leq a$, so that

$$E(y_1 | \mathbf{z}_1, \mathbf{z}_3, I_{it}^* \leq a) = \mathbf{z}_1 \delta_1 + \alpha_1 y_2 + E(u_1 | \mathbf{z}_3, I_{it}^* \leq a) = \mathbf{z}_1 \delta_1 + \alpha_1 y_2 - \gamma_3 \frac{\phi(a - \mathbf{z}_3 \delta_3)}{\Phi(a - \mathbf{z}_3 \delta_3)}.$$

The Mills ratio is then $-\frac{\phi(a - \mathbf{z}_3 \delta_3)}{\Phi(a - \mathbf{z}_3 \delta_3)}$.

Case 3: y_1 is observed only when $a < I_{it}^* \leq b$, so that

$$\begin{aligned} E(y_1 | \mathbf{z}_1, \mathbf{z}_3, a < I_{it}^* < b) &= \mathbf{z}_1 \delta_1 + \alpha_1 y_2 + E(u_1 | \mathbf{z}_3, a < I_{it}^* \leq b) \\ &= \mathbf{z}_1 \delta_1 + \alpha_1 y_2 + \gamma_3 \frac{\phi(a - \mathbf{z}_3 \delta_3) - \phi(b - \mathbf{z}_3 \delta_3)}{\Phi(b - \mathbf{z}_3 \delta_3) - \Phi(a - \mathbf{z}_3 \delta_3)}. \end{aligned}$$

The Mills ratio is then given by $\frac{\phi(a - \mathbf{z}_3 \delta_3) - \phi(b - \mathbf{z}_3 \delta_3)}{\Phi(b - \mathbf{z}_3 \delta_3) - \Phi(a - \mathbf{z}_3 \delta_3)}$.

According to Theorem 19.1 in Wooldridge (2010, p. 794), given \mathbf{z} and I_{it} we can use 2SLS to generate consistent estimates for δ_1 and α_1 by including the Mills ratio as one of the exogenous variables.

Table 1: Summary Statistics

Notes: This table presents the descriptive statistics for the data. The sample contains a total of 5,254 VC firms, investing in 12,670 portfolio companies in the US between 1991 and 2010.

	count	mean	median	max	min	sd
Company Characteristics						
Later-stage dummy	12670	.040604	0	1	0	.1973776
Early-stage dummy	12670	.4631028	0	1	0	.4986537
Seed stage dummy	12670	.2615793	0	1	0	.4395096
Expansion stage dummy	12670	.199143	0	1	0	.3993694
Age	12670	2.479358	1	118	0	6.097491
Round Number of Investors	12670	2.191253	2	18	1	1.498201
IPO	12670	.0901177	0	1	0	.28636
Round amount (thousand \$)	12670	6168.352	3016	2780000	1	25989.08
Lead VC Characteristics						
Fundsize	12670	219.3111	110	15000	0	430.1893
Avgexp	12670	214.9528	78	2821	0	340.8923
Market Concentration						
hhi	2212	.1007075	.0720648	1	.0048333	.0961678
Rtotalvcno	2212	.0929843	.0625	1	.002008	.1073665
Other Market Characteristics						
log(VC Prior 4 Qt. Inflow)	2212	9.900425	10.04591	11.57543	7.497374	.9868855
Value-weighted industry avg. B/M ratio	2212	.2823001	.2553573	1.343295	.0811599	.1411546

Table 2: Relevance of the Instrumental Variable

Notes: This table presents the effects of the instrumental variable *LPR* on the fundraising and financing activities of entrant and dominant VC firms. Entrants are defined as VC firms that invest in a given market for the first time. An incumbent dominant VC firm is defined as a member of a group of VC firms with a combined market share of at least 80 percent (in terms of the number of deals) over a 5-year period. The sample includes observations from all markets with at least five deals in the current year, and more than 25 deals in the past five years. The instrumental variable *LPR* measures the variation of investments in VC of university endowments; see the text for more details on the variable construction. All standard errors are clustered at the market level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Log(dealno)	Log(1+no. of deals involving dominant VCs)	Log(1+no. of deals involving entrants)	Share of deals involving dominant VCs	Share of deals involving entrants	Log(No. of New Funds raised by dominant VCs)	Log(No. of New Funds raised by entrant VCs)
LPR	0.00311*** (0.00102)	-0.00374* (0.00223)	0.0141*** (0.00508)	-0.00292** (0.00116)	0.00453*** (0.00155)	0.429* (0.260)	0.846*** (0.217)
Network measure	-0.0558 (0.0833)	0.772** (0.304)	-0.560* (0.302)	0.551*** (0.180)	-0.219 (0.166)	0.582*** (0.138)	0.0992 (0.157)
Log(deal no, t-1)	0.954*** (0.0117)	1.063*** (0.0202)	0.818*** (0.0265)	0.0670*** (0.0120)	-0.0449*** (0.0122)	0.330*** (0.0242)	0.329*** (0.0236)
Value-weighted industry avg. B/M ratio	-0.0561 (0.0442)	0.175** (0.0726)	-0.436*** (0.112)	0.105** (0.0451)	-0.170*** -0.147* (0.0508)	-0.334*** (0.0770)	(0.104)
Fraction of syndicated deals, t-1	0.0175 (0.0209)	0.0821 (0.0510)	0.395*** (0.0621)	0.0593** (0.0277)	0.179*** (0.0271)		
Log inflow into VC funds	0.0268 (0.0170)	0.00933 (0.0382)	-0.0238 (0.0532)	0.00239 (0.0219)	-0.000440 (0.0245)		
Log(Total fund amounts raised by dominant VCs up to t-1)						0.152*** (0.00288)	
Log(Total fund amounts raised by entrant VCs up to t-1)							0.149*** (0.00321)
Log(Avg. Experience of Dominant VCs)						-0.0162** (0.00631)	
Log(Avg. Experience of Entrant VCs)							-0.00316 (0.00882)
Constant	-0.217 (0.164)	-0.757** (0.364)	-0.710 (0.514)	0.397* (0.210)	0.323 (0.234)	-0.700*** (0.0931)	-0.724*** (0.0842)
Market FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
Observations	2212	2212	2212	2212	2212	2212	2212
Adjusted R^2	0.971	0.705	0.638	0.146	0.228	0.768	0.794

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Table 3: Effect of Market Concentration on Valuation

Notes: This table presents the effect of market concentration on the pre-money valuations of portfolio companies. The sample includes all US portfolio companies that received their first round of funding between 1991 and 2010. Markets are defined based on MSA regions, and industry classifications from Thomson One. The dependent variable is the logged value of the pre-money valuations of portfolio companies. Market concentration is measured by (i) the Herfindahl-Hirschman Index (HHI) based on deal shares, and (ii) the inverse number of VC firms in a given market. All specifications control for the characteristics of portfolio companies at the current funding round (logged company age, dummies for development stages, logged funding amount received, logged number of investors), the characteristics of the lead VC firm (logged number of participating rounds, logged fund size), characteristics of the market (logged capital inflow into VC funds in the prior four quarters, industry book-to-market ratio), as well as include market fixed effects and year fixed effects. The instrumental variable *LPR* measures the variation of investments in VC of university endowments; see the text for more details on the variable construction. Columns 3 and 4 report the results from the 2SLS estimation. Columns 5 and 6 present the results from the 2SLS estimation that corrects for a sample selection bias as described in Section 3.3.2, and report bootstrap standard errors. All standard errors are clustered at the market level.

	(1) logpremoney OLS	(2) logpremoney OLS	(3) logpremoney 2SLS	(4) logpremoney 2SLS	(5) logpremoney 2SLS(selection corrected)	(6) logpremoney 2SLS(selection corrected)
hhi	-0.0485 (0.616)		-6.992* (4.063)		-7.282* (4.089)	
1/total vc no		0.374 (0.835)		-6.007* (3.570)		-6.323* (3.653)
Log(deal no)	-0.0375 (0.0608)	-0.0282 (0.0633)	-0.137* (0.0769)	-0.175* (0.0944)	-0.144* (0.0781)	-0.185* (0.0971)
log(VC Prior 4 Qt. Inflow)	0.0707 (0.0984)	0.0717 (0.0985)	0.0498 (0.0985)	0.0567 (0.0992)	-0.112 (0.122)	-0.0930 (0.118)
Log(Experience of lead VC)	0.00611 (0.0125)	0.00623 (0.0125)	0.00330 (0.0130)	0.00447 (0.0128)	0.00281 (0.0123)	0.00389 (0.0121)
Log(Fund size)	0.203*** (0.0229)	0.203*** (0.0229)	0.207*** (0.0226)	0.203*** (0.0230)	0.208*** (0.0226)	0.204*** (0.0223)
Log(age of company)	0.234*** (0.0292)	0.234*** (0.0292)	0.228*** (0.0296)	0.232*** (0.0295)	0.226*** (0.0294)	0.231*** (0.0290)
Value-weighted industry avg. B/M ratio	0.574 (0.390)	0.570 (0.390)	0.531 (0.390)	0.645* (0.389)	0.491 (0.405)	0.612 (0.391)
Log(round number of investors)	0.426*** (0.0425)	0.427*** (0.0422)	0.402*** (0.0438)	0.411*** (0.0431)	0.397*** (0.0434)	0.407*** (0.0443)
Market network measure	-0.219 (0.524)	-0.212 (0.509)	0.844 (0.920)	-0.457 (0.551)	0.901 (0.904)	-0.452 (0.649)
Company stage dummies	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Market FE	Y	Y	Y	Y	Y	Y
1st Stage coefficient on LPR			0.072 *** (0.015)	0.084*** (0.018)	0.072 *** (0.019)	0.083 *** (0.016)
F-stat for instrument			21.531	21.718	21.725	21.763
Inverse Mills ratio					-3.496*** (1.023)	-3.218*** (0.913)
Observations	3351	3351	3351	3351	3351	3351
Adjusted R^2	0.274	0.274	0.212	0.222	0.213	0.222

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Table 4: Effect of Market Concentration on the IPO Rate of Companies Funded by Inexperienced VC Firm

Notes: This table presents the effect of market concentration on the likelihood of an IPO for portfolio companies backed by VC firms with a low investment experience. A VC firm is considered to have a low investment experience when the number of its prior VC investments in a given market is less than the median number of VC investments of all VC firms in the same market. The sample includes all US portfolio companies that received their first round of funding between 1991 and 2010. Markets are defined based on MSA regions, and industry classifications from Thomson One. The dependent variable is binary, and indicates if a portfolio company experienced an IPO. Market concentration is measured by (i) the Herfindahl-Hirschman Index (HHI) based on deal shares, and (ii) the inverse number of VC firms in a given market. All specifications control for the characteristics of portfolio companies at the current funding round (logged company age, dummies for development stages, logged funding amount received, logged number of investors), the characteristics of the lead VC firm (logged number of participating rounds, logged fund size), characteristics of the market (logged capital inflow into VC funds in the prior four quarters, industry book-to-market ratio), as well as include market fixed effects and year fixed effects. The instrumental variable *LPR* measures the variation of investments in VC of university endowments; see the text for more details on the variable construction. All standard errors are clustered at the market level.

	(1)	(2)	(3)	(4)
	IPO	IPO	IPO	IPO
	OLS	2SLS	OLS	2SLS
hhi	-0.0106 (0.121)	-2.386* (1.318)		
1/total vc number			-0.0387 (0.125)	-2.533* (1.450)
Log(Experience of lead VC)	-0.00203 (0.00306)	0.0000592 (0.00339)	-0.00201 (0.00306)	-0.000225 (0.00334)
Log(Round investment amounts)	0.0127*** (0.00339)	0.00847* (0.00454)	0.0127*** (0.00337)	0.00884** (0.00440)
log(VC Prior 4 Qt. Inflow)	0.0165 (0.0162)	0.00653 (0.0173)	0.0165 (0.0162)	0.0111 (0.0178)
Log(Fund size)	0.00344 (0.00358)	0.00439 (0.00374)	0.00347 (0.00358)	0.00519 (0.00388)
Log(age of company)	0.0292*** (0.00514)	0.0279*** (0.00530)	0.0292*** (0.00514)	0.0294*** (0.00576)
Value-weighted industry avg. B/M ratio	-0.0500* (0.0263)	-0.0381 (0.0302)	-0.0496* (0.0263)	-0.0207 (0.0371)
Log(round number of investors)	0.0346*** (0.0107)	0.0329*** (0.0112)	0.0346*** (0.0107)	0.0319*** (0.0117)
Log(deal no)	-0.0457*** (0.0131)	-0.0999*** (0.0339)	-0.0467*** (0.0137)	-0.121*** (0.0461)
[1em] Company stage dummies	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Market FE	Y	Y	Y	Y
1st Stage coefficient on LPR		0.055 *** (0.011)		0.052*** (0.013)
F-stat for instrument		23.341		17.304
Observations	5445	5445	5445	5445
Adjusted R^2	0.129	0.012	0.129	0.014

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Table 5: Effect of Market Concentration on the IPO Rate of Companies Funded by Experienced VC Firm

Notes: This table presents the effect of market concentration on the likelihood of an IPO for portfolio companies backed by VC firms with a high investment experience. A VC firm is considered to have a high investment experience when the number of its prior VC investments in a given market is higher than the median number of VC investments of all VC firms in the same market. The sample includes all US portfolio companies that received their first round of funding between 1991 and 2010. Markets are defined based on MSA regions, and industry classifications from Thomson One. The dependent variable is binary, and indicates if a portfolio company experienced an IPO. Market concentration is measured by (i) the Herfindahl-Hirschman Index (HHI) based on deal shares, and (ii) the inverse number of VC firms in a given market. All specifications control for the characteristics of portfolio companies at the current funding round (logged company age, dummies for development stages, logged funding amount received, logged number of investors), the characteristics of the lead VC firm (logged number of participating rounds, logged fund size), characteristics of the market (logged capital inflow into VC funds in the prior four quarters, industry book-to-market ratio), as well as include market fixed effects and year fixed effects. The instrumental variable *LPR* measures the variation of investments in VC of university endowments; see the text for more details on the variable construction. All standard errors are clustered at the market level.

	(1)	(2)	(3)	(4)
	IPO	IPO	IPO	IPO
	OLS	2SLS	OLS	2SLS
hhi	0.0912 (0.118)	1.459* (0.847)		
1/total vc number			-0.160 (0.146)	1.437* (0.871)
Log(Experience of lead VC)	0.0107*** (0.00403)	0.0116*** (0.00418)	0.0104*** (0.00400)	0.0122*** (0.00435)
Log(Round investment amounts)	0.0124*** (0.00267)	0.0133*** (0.00292)	0.0123*** (0.00265)	0.0127*** (0.00277)
log(VC Prior 4 Qt. Inflow)	-0.0416** (0.0167)	-0.0410** (0.0171)	-0.0415** (0.0166)	-0.0437** (0.0173)
Log(Fund size)	0.00437 (0.00325)	0.00539 (0.00335)	0.00432 (0.00324)	0.00406 (0.00329)
Log(age of company)	0.0258*** (0.00591)	0.0274*** (0.00595)	0.0256*** (0.00591)	0.0268*** (0.00589)
Value-weighted industry avg. B/M ratio	-0.0848** (0.0326)	-0.0881** (0.0356)	-0.0840*** (0.0323)	-0.0895** (0.0355)
Log(round number of investors)	0.0405*** (0.00953)	0.0444*** (0.00997)	0.0398*** (0.00948)	0.0447*** (0.0101)
Log(deal no)	-0.0287*** (0.0105)	-0.00555 (0.0206)	-0.0338*** (0.0111)	0.00211 (0.0265)
Company stage dummies	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Market FE	Y	Y	Y	Y
1st Stage coefficient on LPR		0.001 *** (0.0003)		0.001*** (0.0002)
F-stat for instrument		18.436		19.841
Observations	7225	7225	7225	7225
Adjusted R^2	0.122	0.083	0.122	0.083

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

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