Competition and Specialization: A Non-Monotonic Relationship[*]

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Abstract

We investigate the relationship between competition and firm specialization in the venture capital (VC) market. Staged financing motivates VC firms to fund entrepreneurs in various states of maturity: startup/seed, early, growth, and so forth, and leads to stage specialization. Contrary to the conventional wisdom that competition always promotes specialization, we find an inverted-U relationship, using panel data on VC funding rounds in the U.S. between 1980 and 2006. We develop a matching model with two-sided vertical heterogeneity, bilateral bargaining and moral hazard to demonstrate that the non-monotonicity is driven by the expected utility VC firms offer to entrepreneurs, via equity stakes, where higher quality entrepreneurs (with more promising business plans) receive greater utility. Competition shifts and rotates the utility schedule, which gives rise to two opposing forces on the returns to specialization as competition intensifies. We then search for validation of the mechanism we propose and we find consistent empirical evidence.

Keywords: Venture capital market, stage specialization, competition, endogenous matching.

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1 Introduction

The conventional wisdom in economics, dating back to Adam Smith, stipulates that competition incentivizes individuals, firms, or countries to exploit the benefits of comparative advantage and, therefore, promotes specialization. In the classical argument, economies of scale arising from competition (and the extent of the market) mediate the division of labor and thus encourage specialization (Smith 1776; Stigler 1951). Grossman and Shapiro (1982), Murphy (1986) and Kim (1989) offer a different explanation for specialization based on demand uncertainty. In such models, the return to specialization increases with market size due to the reduction in the aggregate uncertainty of allocating demand across the different tasks.[1]

We propose a novel role of competition in explaining a venture capital (VC) firm's incentive to specialize. We demonstrate theoretically and empirically that competition can either promote or discourage specialization. In particular, we focus on stage specialization. Staged financing is a distinctive feature of VC and it is well documented that VC firms can concentrate or spread their investments in companies over different stages of maturity: seed/startup, early, growth, and so forth (Campbell 2003).[2] Each stage, in turn, requires significantly different VC skills and inputs.[3] Depending on firm-specific human capital and expertise, the stage allocation of VC investments can differ substantially between and within firms.

Does competition in the VC market contribute to stage specialization? The development of VC in the past few decades provides an ideal research setting. Since 1980, substantial entries and exits of VC firms have taken place across different locations in a wide range of industries in the United States (Hong, Serfes, and Thiele 2013). These dynamics, partly driven by demand fluctuations and business cycles (Gompers, Kovner, Lerner, and Scharfstein 2008), generate varying degrees of competition across markets, which are helpful in identifying its implication on specialization.

We develop a model of specialization that features two-sided vertical heterogeneity, bilateral bargaining, and moral hazard, where: (i) a VC firm's stage expertise (or specialization) depends on the optimal allocation of limited resources across multiple stages, (ii) VC firms with heterogeneous expertise match with entrepreneurs with heterogeneous qualities in each stage, and (iii) VC firms compete on contract terms by transferring utility to entrepreneurs via equity shares. In a stable equilibrium, where a "high-quality" VC firm matches with a "high-quality"

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[1]Garicano and Hubbard (2007, 2009) confirm the positive relationship using data from U.S. law firms.

[2]For example, Sequoia Capital, one of the most well-known VC firms, invests in entrepreneurs in multiple stages (e.g., Google and Yahoo in the seed stage, Zappos.com in the growth stage). In contrast, more than two-thirds of VC firms in a given market year in our sample invest exclusively in one stage. For a recent survey of research on VC, see Da Rin, Hellmann, and Puri (2013).

[3]For example, seed/startup VC firms often work closely with entrepreneurs to define and nurture ideas, early-stage VC firms usually focus more on commercialization and marketing strategies, while growth-stage VC firms may offer assistance in mass production and distribution.

entrepreneur, the utility schedule offered by a VC firm increases in the entrepreneur's quality and responds to competition as bottom-tier VC firms enter the market.[4,5]

We find two opposing forces on a VC firm's incentive to specialize as the market becomes more competitive. On the one hand, competition increases the utilities received by entrepreneurs of every possible quality and the effect tapers off as quality increases. This makes a high-quality entrepreneur relatively cheaper. On the other hand, competition flattens the utility schedule and more so in the low-quality range. This makes a low-quality entrepreneur relatively cheaper. The two opposing forces generate conflicting incentives for a VC firm to specialize and hints at a non-monotonic relationship between specialization and competition.[6]

Using panel data of almost all VC funding rounds between 1980 and 2006 in the United States, we identify an inverted-U relationship between competition and stage specialization; that is, an individual VC firm in a given market specializes more when the market is intermediately competitive and that stage specialization initially increases but eventually decreases with competition.

To test the utility ("price") mechanism in our theoretical rationale, we focus on the value received by an entrepreneur prior to a funding round (i.e., pre-money valuation).[7] Controlling as best we can for other value drivers, we find significantly higher values in more competitive markets. Moreover, the value of an entrepreneurial company without an initial public offering (i.e., low quality) increases faster with competition than that with an IPO (i.e., high quality). This is consistent with our model intuition that the price effect of competition is stronger at the bottom of the quality ladder.

This paper can be considered in the context of a broader literature on specialization. A number of theoretical and empirical papers study the implications of specialization (or diversification) on performance, efficiency, and welfare under various contexts; see, for example, Lang and Stulz (1994), Berger and Ofek (1995) and Santalo and Beccera (2008). Research on the causes of specialization is quite sparse. We identify a novel effect of competition that could work

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[4]One could imagine that higher-quality entrepreneurs hold more promising business ideas, implying, all else being equal, a higher probability of a successful exit, such as an initial public offering (IPO). The utility schedule can be regarded as a wage schedule in a perfectly competitive labor market, where workers are heterogeneous with respect to their skills (and firms are heterogeneous with respect to their productivity). Firms take the wage schedule as given and decide whom to hire. The level of the wage schedule indicates how costly labor is and its slope is a measure of how costly it is for firms to hire workers with better skills (Sattinger 1993; Tuelings 1995; Terviö 2008).

[5]In our model, competition intensifies as new VC firms with less expertise than incumbents enter the market. This is based on two important observations: (i) VC expertise is the main determinant in the match between an entrepreneur and a VC firm (Sørensen 2007) and (ii) entrants possess much less expertise than incumbents (Hong, Serfes, and Thiele 2013). More generally, entry from the bottom can be found in other markets (e.g., physicians, experienced managers) where the supply of quality is relatively inelastic.

[6]Note that a VC firm could invest in multiple stages and specialize in one stage more than others. See Sections 2.1 and 3.2 for details about how we model stage specialization.

[7]The pre-money valuation is approximately proportional to the equity stake held by entrepreneurs.

against specialization.[8] Our intuition can be applied to other markets (e.g., the match between employers and workers in labor markets), especially when two-sided vertical heterogeneity and contract incompleteness play important roles.

Several strands of literature in financial economics are also relevant. A number of papers document that VC firms may specialize by focusing their investments in a particular stage (Sahlman 1990; Barry 1994) and such specialization is related to various VC characteristics, including age, size, and location (Han 2009). Other papers look into the scope of an optimal portfolio for a single VC firm (Inderst, Mueller, and Muennich 2007; Fulghieri and Sevilir 2009). Hochberg, Mazzeo, and McDevitt (2013) and Gompers, Kovner, and Lerner (2009) examine industry specialization.[9] However, no previous papers address the market determinant of stage specialization.

The rest of the paper is organized as follows. Section 2 sketches the theoretical model and the main intuition. Appendix B presents further technical details. Section 3 describes the data. Section 4 presents the empirical results and robustness tests. Section 5 concludes the paper.

2 A Market Equilibrium Model of Stage Specialization

One of the most important sources of startup finance for entrepreneurs is VC. Venture-backed companies produced revenue equal to 21% of the U.S. gross domestic product and created 11% of private sector jobs in 2010.[10] In addition, VC activities fuel the economy by generating non-venture-related businesses and jobs (Samila and Sorenson 2011). Though the success of VC investments is closely related with a VC firm's ability to specialize (Gompers, Kovner, and Lerner 2009), the literature does not adequately explore the underlying mechanism that leads to specialization.

Our theoretical model consists of the following building blocks. In Section 2.1, we model a VC firm's stage specialization decisions, taking market structure as given. A VC firm decides on how to allocate its resources across two stages, and the profitability of each stage is determined

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[8]Our paper is similar in spirit with the papers that investigate the link between innovation and competition and identify two opposing forces on the R&D incentives as market competition intensifies. Aghion et al. (2005) and van Lamoen et al. (2010) show that the competition–innovation relationship exhibits an inverted-U shape. In contrast, Hashmi (2013) finds evidence for a negative relationship, because one of the two effects is always more dominant. Nevertheless, in addition to our model and research question being very different from those in the innovation literature, the two opposing effects of Aghion et al. (2005) apply only to different firms (depending on how far they are from the technological frontier) and not to the same firm, as is the case in our paper. Our identification strategy relies on the change of specialization of a *given* firm (in a given market) and how it responds to changes in the competitive environment over time.

[9]Our paper is also related to that of Inderst and Mueller (2004), who use a search model to investigate the effect of capital market competition on pricing, contracting, and value creation. However, the authors assume homogeneous VC firms and entrepreneurs and do not focus on specialization. We use an endogenous matching framework that allows us to add rich heterogeneities in VC expertise and entrepreneur quality. These heterogeneities not only feature prominently in the VC market (e.g., Hsu 2004; Sørensen 2007; Uetake 2012), but also help us understand the differential effect of competition on entrepreneurs and VC firms.

[10]See "Venture Impact: The Economic Importance of Venture Backed Companies to the U.S. Economy," 2011.

in the market. Intuitively, the optimal resource allocation, which leads to a certain degree of stage specialization, depends on the marginal benefit and cost in each stage. In our setting, specialization benefits VC firms through two channels: (i) It raises the probability of an entrepreneur getting funded (demand effect) and (ii) it increases the VC firm's rank with respect to expertise and thus attracts entrepreneurs with more promising business plans (quality effect).

Then, in Section 2.2, we model how VC firms match with entrepreneurs in the market. In each stage, a continuum of entrepreneurs with heterogeneous qualities is matched one to one to VC firms with heterogeneous expertise (or rank).[11] VC firms compete on contract terms by transferring utilities to entrepreneurs through equity shares. In a stable equilibrium, an entrepreneur's utility increases in his quality. The equilibrium matching in each stage is positive assortative: high-ranked VC firms fund high-quality entrepreneurs, and low-ranked VC firms fund low-quality entrepreneurs.

Finally, in Section 2.3, we allow VC firms with low expertise to enter the market and match with previously unfunded entrepreneurs. The effect of competition on specialization is driven by the 'price' (utility) VC firms have to pay. When a VC firm devotes more resources in a particular stage, its rank in that stage increases, allowing the VC firm to match with higher-quality entrepreneurs. Higher-quality entrepreneurs, in turn, are "more expensive" because they command a higher equilibrium utility. Competition affects incentives to specialize through the relative prices in different stages.

The entry of bottom-tier VC firms increases the equilibrium utility offered to entrepreneurs, including those still matched with incumbents; however, the slope of the utility function (with respect to entrepreneur quality) decreases. This gives rise to two effects on a VC firm's incentive to specialize: On the one hand, competition forces incumbent VC firms to offer higher utility to retain their matched entrepreneurs (i.e., it shifts the utility schedule upward). This effect transmits from the bottom up and dissipates as it moves higher up the expertise/quality ladder. As a result, entry has a stronger impact on low-quality entrepreneurs, whose utilities increase relatively more. On the other hand, stronger competition decreases the equity stake held by VC firms and weakens their incentives to compete aggressively for higher-quality entrepreneurs. This leads to a flatter utility function with respect to entrepreneur quality (i.e., it rotates the utility function).[12] Similarly to the impact on the utility level, the effect on the utility slope is stronger at the bottom.

Without loss of generality, consider a VC firm that is initially more specialized in stage 1 than in stage 2. Positive assortative matching (PAM) implies that the VC firm matches with

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[11]We use rank to describe VC expertise. Those VC firms that specialize more in a given stage also rank higher in that stage. In addition, we allow VC firms to be ex ante more specialized in one stage than in the other. Therefore, the rank of a VC firm's expertise need not be the same in different stages.

[12]Our results depend crucially on entrepreneur heterogeneity, an important feature in the VC market. For example, if entrepreneurs are homogeneous in quality, the slope of their utility function with respect to quality would be zero. Alternatively, a higher degree of heterogeneity in entrepreneur quality makes the utility function steeper.

a higher-quality entrepreneur in stage 1 than in stage 2. As competition intensifies, the utility offered to the entrepreneur in stage 2 increases more than in stage 1, since the match in stage 2 is closer to the bottom of the market. This incentivizes the VC firm to devote more resource to stage 1 and leads to more specialization than at the initial level. Furthermore, competition rotates the utility schedule and the slope of the utility function decreases more at the bottom. As a result, the lower-quality entrepreneur in stage 2 becomes relatively cheaper, which leads to less specialization in stage 1 than at the initial level.[13]

2.1 Specialization Decisions of a Single VC Firm

Two empirical regularities motivate our model of a VC firm's investment strategies. First, 99% of VC investors of a given entrepreneurial company participate in only one stage.[14] Second, VC firms can invest in multiple stages across different entrepreneurs and only 34% focus on investing in a single stage throughout our sample period.[15]

In our model, a VC firm can fund multiple startup companies (entrepreneurs) in stage 1 (e.g., seed stage) and stage 2 (e.g., growth stage), indexed by $s = 1, 2$.[16] For a given entrepreneur, a VC firm can participate in either stage 1 or stage 2, but not in both. Each VC firm decides how many resources (e.g., human capital investments) to devote to each stage, denoted τ_1 and τ_2, respectively, with an exogenous per-unit cost w_s to implement τ_s. If $\tau_1 \geq \tau_2$, the firm is more specialized in stage 1 and an increase in τ_1/τ_2 represents a further increase in specialization relative to the initial level.

Let $\overline{\Pi}_s(\tau_s)$ denote a VC firm's profit from funding a particular EN in stage s and let $q_s(\tau_s)$ denote the probability of securing a deal.[17] A VC firm chooses τ_1 and τ_2 to maximize the expected payoff

$$\max_{\{\tau_1, \tau_2\}} q_1(\tau_1)\overline{\Pi}_1(\tau_1) + q_2(\tau_2)\overline{\Pi}_2(\tau_2) - w_1\tau_1 - w_2\tau_2. \tag{1}$$

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[13]Section 2.3 offers intuition about the equilibrium response of the utility function.

[14]The investors may participate in multiple rounds in the same stage.

[15]These empirical regularities were also confirmed in an interview we had with a venture capitalist, who stated that most VC firms invest actively only in one stage for a given company and then either cash out or retain their position in the company.

[16]We focus on two stages for tractability. Our model can be extended to allow for multiple stages.

[17]Alternatively, $q_s(\tau_s)$ can be interpreted as the capacity of the VC firm, that is, the number of companies it can fund in a given stage. A higher q_s suggests that a VC firm invests in more projects in stage s. If a company is not funded (given that funding is probabilistic), then we assume that it obtains non-VC funding and has no effect on other VC firms or entrepreneurs in the market; allowing it to search for funding from other VC firms in the market would complicate the analysis unnecessarily. We believe our setup is reasonable. Imagine a situation where each investment stage involves many periods, with entrepreneurs arriving at each period. In each period, VC firms match one to one with entrepreneurs and offer contracts, but each entrepreneur may reject a contract with probability $1 - q$. After a rejection, it is too late for the VC firm to seek other entrepreneurs from the same period and it waits for the next period arrival.

Equation (1) implies that specialization benefits VC firms through two distinct channels: *First*, specialization τ_s increases the demand $q_s(\tau_s)$. *Second*, specialization adds more value to the venture and raises the probability of 'success' (and profit), that is, $\overline{\Pi}_s$ increases in τ_s.[18] The first order conditions for an interior solution are

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\begin{aligned}
\frac{dq_1(\tau_1^*)}{d\tau_1}\overline{\Pi}_1(\tau_1^*) + q_1(\tau_1^*)\frac{d\overline{\Pi}_1(\tau_1^*)}{d\tau_1} &= w_1 \\
\frac{dq_2(\tau_2^*)}{d\tau_2}\overline{\Pi}_2(\tau_2^*) + q_2(\tau_2^*)\frac{d\overline{\Pi}_2(\tau_2^*)}{d\tau_2} &= w_2.
\end{aligned}
\tag{2}
$$

Equation (2) is intuitively appealing: The left-hand side is the marginal benefit of τ_s and the right-hand side is the marginal cost. As we argue below, competition affects a VC firm's incentive to specialize through $\overline{\Pi}_s(\tau_s)$ and its derivative $d\overline{\Pi}_s(\tau_s)/d\tau_s$.

2.2   Model of the VC Market

We assume that the VC market consists of a continuum of risk-neutral entrepreneurs and a continuum of risk-neutral VC firms. Each entrepreneur seeks funding from VC firms over two investment stages, indexed by $s = 1, 2$. Based on the empirical regularities established in Section 2.1 and for simplicity, we assume away any dependence between the two stages; that is, stage 2 is a replication of stage 1.[19] We index entrepreneurs by $i \in E = [0, \overline{E}]$, with $H(i)$ as the distribution of i and $h(i)$ as its density; we index VC firms by $j \in V = [0, \overline{V}]$, with distribution $G(j)$ and density $g(j)$. The distributions can differ across stages. The game unfolds as follows:

- Date 1. Entrepreneurs conceive business ideas for new ventures.

- Date 2. Each VC firm chooses its stage specialization.

- Date 3. Stage s investment: Each entrepreneur matches with a VC firm that offers capital in exchange for an equity stake in the venture.

- Date 4. Stage s effort: Entrepreneurs exert private effort (moral hazard with limited liability).

- Date 5. All returns are realized.

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[18]We could also capture a firm's degree of specialization by focusing on the output of specialization, $q_1(\tau_1^*)/q_2(\tau_2^*)$, which measures the relative number of deals in each stage. To the extent this ratio is monotonic to τ_1^*/τ_2^*, our conclusions remain the same. In the empirical analysis later, we measure specialization using the relative number of deals because we cannot observe the inputs τ_s.

[19]One way to justify this assumption is to assume that if the venture succeeds in stage 1, the VC firm cashes out and the entrepreneur starts stage 2 fresh, where it matches with a new VC. The alternative assumption is to allow the VC firm to retain its position in the company after stage 1 ends successfully and cash out if and only if stage 2 succeeds. This would complicate the analysis significantly by making the two stages interdependent, without adding new insight.

On Date 1, the quality of entrepreneur i's idea is $\mu(i)$, which is increasing, concave, continuously differentiable in the vertical ranking i, and constant across stages; μ is common knowledge.

On Date 2, each VC firm makes the specialization choice τ_s. VC firm j's stage management expertise $x_s(j(\tau_s))$ increases in j and we assume the ranking $j(\tau_s)$ increases in τ_s; x_s is common knowledge.

On Date 3, each VC firm matches endogenously with one entrepreneur in stage s. To capture the idea that entrepreneurs rely heavily on the management expertise of VC firms, the *match quality* $\Omega \equiv \Omega(\mu, x_s) > 0$ strictly increases in entrepreneur quality μ and VC expertise x_s, while quality and expertise are complements, that is, $\partial^2 \Omega(\mu, x_s)/(\partial x_s \partial \mu) > 0$. VC firm j then offers its entrepreneur i in stage s a fixed amount of capital K_{ijs}, with an exogenously given cost $r > 0$, in exchange for an equity stake $1 - \lambda_{ijs}$.[20] We assume that VC firms have all the bargaining power when they make offers to entrepreneurs. The utility of an entrepreneur who remains unmatched is zero. This gives a rank i entrepreneur an expected utility $u(i)$ and generates an expected payoff $\overline{\Pi}(\Omega)$ to the VC firm that matches with i.[21]

On Date 4, each entrepreneur exerts a stage-s private effort e_s to turn an idea into a marketable product.[22] The non-contractibility of the entrepreneur's effort leads to a typical moral hazard limited liability problem. An entrepreneur's stage-s private effort determines the likelihood of success ($Y_s = 1$), where $\text{Prob}[Y_s = 1 | e_s] = e_s$.[23] The disutility of effort is given by $c(e_s) = e_s^2/2$.

On Date 5, the gross profit of a venture is $\pi(\Omega) > 0$ if the venture succeeds in stage s and 0 otherwise, where we assume $\pi(\Omega)$ to be increasing and concave in the matching quality Ω.[24]

As Sørensen (2007), we focus on a PAM equilibrium: A high-ranked entrepreneur is funded by a high-ranked VC firm and neither party has an incentive to deviate from the match.[25] We derive the equilibrium utility of entrepreneurs $u^*(i)$ to ensure a stable equilibrium and show that $u^*(i)$ increases in i in Appendix B. As we explain next, it affects both $\overline{\Pi}_s$ and $d\overline{\Pi}_s/d\tau_s$.

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[20]Although common stock is used in practice, the most commonly used security is convertible preferred stock (Kaplan and Strömberg 2003). In the theoretical model, we assume that the security is common stock for simplicity and tractability.

[21]$u(i)$ and $\overline{\Pi}(\Omega)$ are on the same bargaining frontier and inversely related.

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

[23]Success in stage 1 means that the company moves on to stage 2 and success in stage 2 means that the company goes public.

[24]The matching model is similar to that of Hong, Serfes, and Thiele (2013). The differences are: (i) Hong et al. are not concerned with stage specialization and thus their model has only one stage and (ii) they also endogenize the capital investment of a VC firm, while in this paper it is exogenously given.

[25]In other words, in equilibrium, entrepreneurs with high rankings will not be funded by VC firms with low rankings. A characteristic that is very important in the VC market is the brand name. Reputation leads to matching the most successful VC firms with the most talented entrepreneurs (see Campbell 2003, p. 30).

2.3 Specialization and Competition

We focus on how a VC firm's optimal choices τ_1^* and τ_2^* depend on competition. The VC market has experienced substantial entry since 1980 (Hochberg, Ljungqvist, and Lu 2010) and the majority of entrants are much less experienced than incumbents. As described by Hong, Serfes, and Thiele (2013), the median incumbent experience is 80 prior deals, while the median entrant experience is only 10 deals in other markets.[26] Motivated by these empirical findings, we focus on changes in competition induced by the entry of low-expertise VC firms. Changes in market structure due to entry are in the form of comparative statics.

2.3.1 Equilibrium Response of u^*

Proposition 1 in Appendix B shows that a more competitive market is associated with a higher $u^*(i)$ which has a flatter slope (with respect to entrepreneur quality). In addition, the impact on $u^*(i)$ and the slope is bigger on lower qualities. To understand the intuition, we exploit the properties of the bargaining (Pareto) frontier and, more specifically, the slope and curvature. As Figure B.5 demonstrates, the bargaining frontier for each VC–EN pair in stage s is downward sloping and concave, with the slope ranging from zero (when the utility of the entrepreneur is the lowest) to -1 (when the profit of the VC firm is zero).[27]

Imagine a simple setup with one investment stage and a countable number of VC firms and entrepreneurs. Figure 1 assumes three matched VC–EN pairs in the market, ranked from the highest quality pair (pair 1) to the lowest (pair 3). The value of the outside option for EN3 is zero; however, EN3's utility is greater than zero due to limited liability and is the lowest possible, given that VC firms have all the bargaining power.[28] As we move up the ladder, EN2 is given the minimum possible utility plus VC3's incremental profit if the VC firm matches with EN2 instead, and so on.

The market becomes more competitive when VC4 enters the market. Although VC4 funds EN4 in equilibrium, VC4 bids up EN3's outside option and subsequently VC3 must match up EN3's incremental utility Δu_3. Since the slope of the bargaining frontier is less than one in absolute terms, the decrease in VC3's profit is less than the increase in EN3's utility, $|\Delta \overline{\overline{\Pi}}_3| < \Delta u_3$. Worse off by $|\Delta \overline{\overline{\Pi}}_3|$, VC3's willingness to pay for EN2 increases exactly by $|\Delta \overline{\overline{\Pi}}_3|$, which

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[26]Entrants are not necessarily inexperienced "rookies" and may be incumbents in other markets (Hochberg, Ljungqvist, and Lu 2010).

[27]The latter is the efficient outcome because it is associated with 100% equity for the entrepreneur and, as a result, with the strongest incentives for effort. Limited liability gives rise to a non-transferable utility (NTU) environment, where utility is transferred (imperfectly) via the equity share. This is a very reasonable assumption for the VC market, since entrepreneurs are wealth constrained and side payments are rare (Sørensen 2007). A higher equity share to the entrepreneur increases his or her utility and mitigates the inefficiency from moral hazard by inducing higher effort. Therefore, as we move down the bargaining frontier, the entrepreneur's utility increases and the VC firm's profit decreases; however, the sum of the two increases (due to higher efficiency). We derive the Pareto frontier in Appendix B (see equation (B.10)).

[28]Figure B.5 shows that the entrepreneur's utility in the absence of competition is $\pi(\Omega)^2/8$.
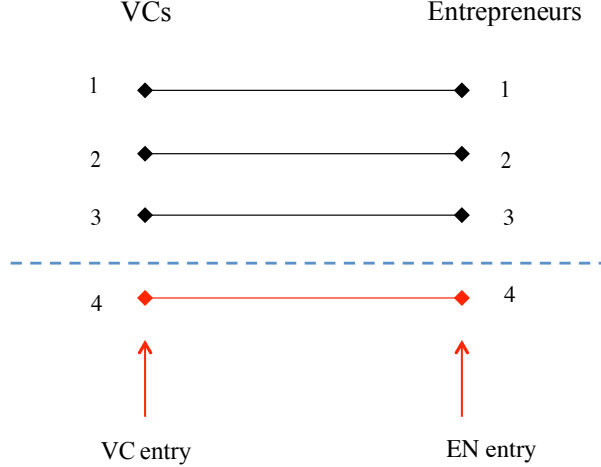
Figure 1: Positive assortative VC–EN matching and the effect of entry

suggests that the increase in EN2's utility is $\Delta u_2 = |\Delta \overline{\Pi}_3|$. This logic implies that $\Delta u_2 < \Delta u_3$. By continuing this line of reasoning, we can show that $\Delta u_1 < \Delta u_2 < \Delta u_3$. This explains why u^* increases more for low-quality entrepreneurs (provided that entry takes place at the low end of the market). Competition creates a *ripple effect* that diminishes as we are moving up the quality ladder.

Next, we elaborate on the finding that the slope of $u^*(i)$ decreases more at the lower end of the ladder as competition intensifies. First, we could rank the slopes of the bargaining frontiers at the equilibrium positions for the three VC–EN pairs: $1 - 1$, $2 - 2$, and $3 - 3$. As we move up the quality ladder across VC–EN pairs, the bargaining frontier shifts out while the equilibrium u^* on a given bargaining frontier increases at the same time. For a fixed u^*, the frontier flattens as it stretches out (i.e., a positive effect).[29] On a fixed bargaining frontier, the slope becomes steeper with a larger u^* due to concavity (i.e., a negative effect).[30] Under reasonable conditions, the negative effect dominates (for more details, see Appendix B) and the following inequalities hold:

$$\frac{|\Delta \Pi_3|}{\Delta u_3} < \frac{|\Delta \Pi_2|}{\Delta u_2} < \frac{|\Delta \Pi_1|}{\Delta u_1}. \tag{3}$$

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[29]In other words, it is easier for a higher-quality VC firm to transfer surplus to its assigned entrepreneur. Legros and Newman (2007) show that this is one of the two sufficient conditions for PAM. Under the assumption that the match quality Ω is increasing in x_s, the condition is satisfied by our model (see Appendix B for more details).

[30]The bargaining frontier is concave because, as u increases, the VC firm needs to increase the equity given to the entrepreneur at a higher rate in order to transfer one more unit of utility. This stems from the decreasing returns of entrepreneur effort, due to a standard convex cost of effort function. Consequently, VC firm profits decrease faster as entrepreneur utility increases.
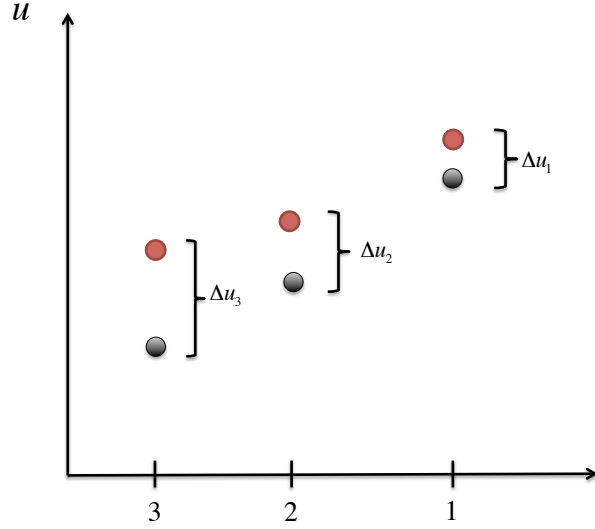
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Figure 2: Equilibrium EN utilities

As we have shown before, $|\Delta\Pi_3| = \Delta u_2$ and $|\Delta\Pi_2| = \Delta u_1$. So, the above inequalities become

$$\frac{\Delta u_2}{\Delta u_3} < \frac{\Delta u_1}{\Delta u_2},$$

which, combined with the previous finding that $\Delta u_3 > \Delta u_2 > \Delta u_1$, yields

$$\Delta u_3 - \Delta u_2 > \Delta u_2 - \Delta u_1. \tag{4}$$

This implies that the slope of equilibrium utility with respect to quality decreases more at the lower end of the market, as illustrated by Figure 2. The proofs in Appendix B confirm this intuition in the case of continuous types.[31]

Overall, the equilibrium response of u^* stems from two properties of the bargaining frontier: The slope of the bargaining frontier is less than one (in absolute terms) and the frontier is concave. These are fairly general properties that can be attributed to contract incompleteness and diminishing returns to effort, respectively.

2.3.2 Specialization and u^*

Combining the properties of u^* with the VC's first order conditions in (2) introduces two opposing effects on a VC firm's incentives to specialize. Assume that initially, $\tau_1^* \geq \tau_2^*$, i.e., the

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[31]The NTU assumption is crucial for these results. In a transferable utility (TU) environment, the Pareto frontier would be linear with slope -1. The entry of new VC firms would shift $u^*(i)$ up in a parallel fashion. All entrepreneurs would be similarly impacted. Nevertheless, as we have already argued, the NTU assumption (due to, more broadly, contract incompleteness) fits the VC market better.

firm has invested more resources in stage 1 than in stage 2. It follows from the PAM that the VC firm matches with a higher quality entrepreneur in stage 1.

As competition intensifies, the VC firm's profit per deal, $\overline{\Pi}_s$, decreases while u^* increases. Hence, the marginal benefit of the stage-s investment, that is, the left-hand side of (2), decreases and, as a result, both τ_1^* and τ_2^* decrease. However, $\overline{\Pi}_s$ decreases more in the stage that funds lower-quality firms (since u^* increases more for low-quality entrepreneurs), suggesting that the stage 2 marginal benefit decreases more than that in stage 1. As a result, τ_2^* decreases more than τ_1^*, so τ_1^*/τ_2^* increases: *more specialization* compared to the initial level.

On the other hand, it becomes cheaper for a VC firm to fund higher-quality entrepreneurs through a higher stage-s investment as competition intensifies. This is because $du^*(i)/di$, which measures how much more utility a VC firm needs to give to a higher-quality entrepreneur, decreases (so $d\overline{\Pi}_s/d\tau_s$ increases; see also (B.15)). Therefore, the marginal benefit of the stage-s investment increases and the VC firm will increase both τ_s^*'s. Furthermore, the impact is bigger at the lower end of the market and so τ_1^*/τ_2^* decreases: *less specialization* compared to the initial level.

Which effect dominates the other becomes an empirical question, which we address next. Consistent with the presence of the two opposing effects, our empirical results indicate that stage specialization is inverse U-shaped with respect to the VC market structure. Starting from very concentrated markets, a decrease in concentration increases stage specialization. This continues up to a point. For very competitive markets, further increases of competition decrease stage specialization.[32]

3 Data

3.1 Sample Construction and Market Definition

We build our sample from Thomson Economics' VentureXpert database, which provides representative coverage of U.S. venture activities.[33] The dataset contains round-level information on VC investments (e.g., round date, round amount, identity of investors), limited information on VC-backed portfolio companies (e.g., development status on the round date, industry group), and event dates (e.g., for IPOs, acquisitions, bankruptcies). Our analysis focuses on VC investments between 1980 and 2006 made by U.S.-based VC firms.[34]

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[32]When all VC firms change their degree of specialization as an initial response to a market structure change, there will be continuing effects on $u^*(i)$ (because the quality distribution of VC firms will change) until the market settles into a new equilibrium. We do not pursue this further since it is beyond the scope of this paper. The main purpose of the theoretical model is to demonstrate the existence of two opposing forces on VC firm specialization decisions as the market grows.

[33]See Lerner (1995), Gompers and Lerner (1999), and Kaplan, Sensoy, and Stromberg (2002) for discussions about the VentureXpert database and data coverage.

[34]We exclude investment rounds involving individuals, undisclosed VC firms, angel, and buyout funds. We focus on entrepreneurial companies in the contiguous states and exclude those in Hawaii, Alaska, or Puerto Rico.

The VC market is highly segmented (Sorenson and Stuart 2001; Sørensen 2007; Hochberg, Ljungqvist, and Lu 2010; Hochberg, Mazzeo, and McDevitt 2013). Following the literature, we use industry and geography combinations to delineate economic markets. We interact six broad industry groups (as defined by the VentureXpert database) with two alternative geographies: Metropolitan Statistical Areas (MSAs) and states.[35] An MSA is usually smaller than a state and is useful for aggregating VC activities in the vicinity of big cities. Alternatively, VC firms and entrepreneurs may receive different government support through favorable tax policies, state VC programs, and other support programs. Thus we perform our analysis and report the results for both definitions.

The unit of observation for our main specification is a VC firm in a given market–year. Our sample contains 672 MSA–industry markets with 7345 distinct MSA–industry–year observations and 246 state–industry markets with 4196 distinct state–industry–year observations between 1980 and 2006.

3.2 Measuring Stage Specialization

The measure of specialization $stgspec_{fmt}$ is computed using the stage composition of VC firms' investment activities in a given market year. We use four mutually exclusive stages to classify VC investments: seed/startup, early, growth, and other stage, representing 13%, 23%, 50%, and 12%, respectively, of the total investment rounds in our sample.[36] From a VC firm's perspective, the maturity of entrepreneurial companies, the degree of uncertainty, the type of expertise, and the monitoring required usually vary considerably across stages. For example, seed stage companies usually have no commercial operations; early-stage companies often begin operations without commercial manufacturing and sales; growth-stage companies usually start to generate revenue. VC firms may subsequently require on-site residency for seed-stage companies (e.g., Sequoia Capital) and prefer to be the first investor or business partners in growth-stage companies. Many industry practitioners recognize the stage classifications we adopt here.

The stage specialization measure is computed as the sum of the squared shares of a VC firm's investments in each stage, that is, a Herfindahl–Hirschman Index (HHI) based on stage investment composition. This equals one if VC_f concentrates its investment on a particular stage and 0.25 if VC_f spreads its investment equally across all stages. Our measure of stage specialization is analogous to the VC firm's industry specialization measure proposed by Gompers, Kovner, and Lerner (2009).

We use two alternative definitions of investment shares for $stgspec_{fmt}$: one based on the fraction of deals in each stage and the other based on the imputed dollar value invested in each

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[35]The six industry groups are biotechnology, communications/media, computer related, medical health life sciences, non-high tech, and semiconductors.

[36]The growth stage includes both the expansion and later stages, as defined by the VentureXpert database. Since there is no clear distinction between expansion and later stages, we combine them into a single category. About 53% of other-stage VC rounds are bridge loans and 22% are open market purchases.

stage.[37] The deal share gives equal weight to all funding rounds, while the value share favors rounds with larger stakes. Despite quantitative differences, the stage specialization measures based on deal and value shares are highly correlated (with a correlation coefficient 0.91). Our results are very similar using either definition.

Table 1 displays the summary statistics of $stgspec_{fmt}$. An average VC firm is highly specialized. For example, mean specialization based on deal share is 0.92 in the MSA market and 0.9 in the state market. The high average is primarily driven by the strong presence of low-volume VC firms, which usually participate in one investment round in a market year. These VC firms are typically younger and less experienced, manage a smaller number of funds, operate within a smaller geographical scope, and focus on a narrower spectrum of the industry. Mean specialization is 0.75 if we focus only on VC firms with at least two funding rounds in a market year. All together, low-volume VC firms account for almost 80% of our observations.[38]

Despite the high average, there is a substantial amount of variation in specialization. The panel structure of our data allows us to introduce VC market-specific fixed effects and to focus on the change in specialization of the same VC in the same market over time.

3.3 Measuring Competition

The intensity of competition is measured using the HHI or the number of VC firms in a given market. Similar to the stage specialization measure, we compute the HHI using either the deal share or the imputed dollar value share.[39] We report our results for all three measures of competition.

Table 1 presents the descriptive statistics of competition measures. The HHI based on the dollar share is approximately equivalent to a (symmetric) duopoly in an MSA market (0.46) and to a triopoly (0.37) in a state market.[40] Due to the presence of a large number of low-volume VC firms, the average MSA and state markets are populated by 13 and 20 VC firms, respectively.

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[37]The dollar value each VC firm has invested in a given round is not readily available. Instead, VentureXpert reports the total round amount (made by all investors that participated in that round) and the total amount a VC firm has invested in a given entrepreneurial company. We impute a VC firm's round investment value by distributing the total investment in a portfolio company into each round in which the VC firm has participated according to round amounts. For example, suppose an entrepreneur received $1 million in total from VC_i that participated in rounds 1 and 4. If the total amounts raised in rounds 1 and 4 are $2.5 million and $7.5 million dollars, respectively, then the imputed investment for VC_i in round 1 is 1*2.5/(2.5+7.5)=0.25 million and in round 4 it is 1*7.5/(2.5+7.5)=0.75 million.

[38]We decided to include low-volume VC firms in our later analysis for two reasons. First, there are many of them (nearly 80% of observations). Second, the return to specialization may be especially important for low-volume VC firms, which are usually more resource constrained than high-volume firms. As we discuss shortly, the non-monotonic relationship between specialization and competition is robust to the exclusion of low-volume VC firms.

[39]The HHI based on deal shares is highly correlated with that based on dollar value shares, with a correlation coefficient of 0.93.

[40]We expect a generally lower concentration ratio in a state market since states are usually broader than MSAs.

The intensity of competition varies substantially across markets. For example, more than 900 VC firms invested in computer-related deals in California in 1999, while only one VC firm invested in biotechnology in Alabama in the same year. Thus, it is important to account for VC market heterogeneities. Our empirical specifications combine instrumental variables with a number of fixed effects to identify the causal effect of competition.

3.4 Other VC Characteristics

We use a parsimonious set of time-varying VC characteristics to control for other determinants of specialization. For example, a young VC firm may start off by focusing on one particular stage and gradually build up its diversified portfolio. We control for such a growth trajectory using VC cumulative market experience as measured by the total number of deals in prior years; VC market age measured by the difference between a calendar year and the first year the VC started investing in the target market; and VC experience at the firm level, measured by the total number of deals in which the firm participated in all markets in previous years. To account for other firm-level investment strategies that contribute to specialization, we include the number of funds under management, the number of geographical markets, and the number of industries the VC firm invested in during a given year. The control variables are presented in Panels A and B of Table 1.[41]

4 Results

4.1 Descriptive Evidence of Non-Monotonicity

We plot the average $stgspec_{fmt}$ over the range of market concentration and then use a quadratic fit to visualize the relationship between competition and stage specialization.

Figure 3 provides evidence suggestive of a non-monotonic relationship between competition and stage specialization and the shape of the fitted curve resembles an inverted-U.[42] One may note that the fitted values in the figure do not always directly cross through the right tail where many observations are concentrated (e.g., graph e in Figure 3). This is because a competitive market (along the left tail) is populated by a larger number of VC firms and therefore more stage specialization observations. This gives heavier weights to fit the left tail.[43] In all graphs, VC firms tend to specialize the most in the intermediately competitive market when the HHI (based on various measures) is between 0.5 and 0.6.

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[41]Besides the variables reported in Table 1, we experiment with a large set of controls (e.g., fraction of syndicated deals, fund growth rate). However, these explain little variation in stage specialization measures and are not included in our specifications.

[42]We divide the support of the concentration ratio into 100 bins and then plot the average stage specialization for each bin in the figure.

[43]Consistent with our explanation, the 95% confidence interval is tighter in the low-concentration region.

We note that around $70-80\%$ of VC firms participate in only one deal in a given market year. To ensure that the relationship between competition and stage specialization is not driven merely by the low-volume VC firms, we plot the same relationship after excluding VC firms without at least two deals in a given market year. Figure 4 shows a similar inverted-U relationship between competition and stage specialization, where the average specialization is highest when the market is intermediately competitive when the HHI is around 0.6.

Nevertheless, we must exercise caution when making inferences based on aggregated patterns alone, since this may risk overlooking heterogeneities across VC firms and markets. Next, we formally establish the non-monotonicity in Sections 4.2 and 4.3.

4.2 Descriptive Relationship between Competition and Specialization

We formalize the correlation between competition and stage specialization by estimating

$$stgspec_{imt} = \beta_1 hhi_{mt} + \beta_2 hhi_{mt}^2 + \theta x_{imt} + \gamma x_{it} + \delta_{im} + \delta_t + \varepsilon_{imt} \tag{5}$$

for VC firm i, market m, and calendar year t, where hhi_{mt} and hhi_{mt}^2 are market concentration and its squared counterpart, respectively; x_{it} and x_{imt} are time-varying VC characteristics and VC market characteristics, respectively; the δ_{im} are fixed effects that absorb any VC market-specific time-invariant unobservable factors; and the δ_t are year fixed dummies. We include fixed effects δ_{im} and δ_t in all specifications.

Table 2 displays the results of (5) in the MSA markets (left panel) and state markets (right panel) in Panels A to C, for the three competition measures respectively. Panel C uses the reciprocal of the number of VC firms (instead of the VC firm count) in the regression so that it moves in the same direction as the HHI and approaches one when the market becomes more concentrated. The dependent variables are stage specialization measures based on either deal shares or dollar shares. Since $stgspec_{imt}$ varies by firm market while hhi_{mt} varies by market, we cluster our standard errors at the market level to account for within-market correlation.

We start by including concentration ratio as the only explanatory variable and gradually add more controls. In a benchmark analysis, we regress $stgspec_{imt}$ on $log(hhi_{mt})$ without any additional control variables. The linear-log specification allows a non-linear effect of competition. Non-monotonicity is prohibited by construction. Column (1) in Table 2 suggests that VC firms generally specialize less as competition intensifies (i.e., the estimated effects of $log(hhi)$ and $log(1/nvc)$ are positive). This differs from the conventional intuition that competition always promotes specialization. However, if competition promotes specialization before starting to discourage specialization and the empirical specification forces this relationship to be monotonic, then the estimated effect of competition could be either positive or negative. For example, if observations cluster in the upward-sloping region of an inverted-U curve, then the estimated effect of concentration could be positive.
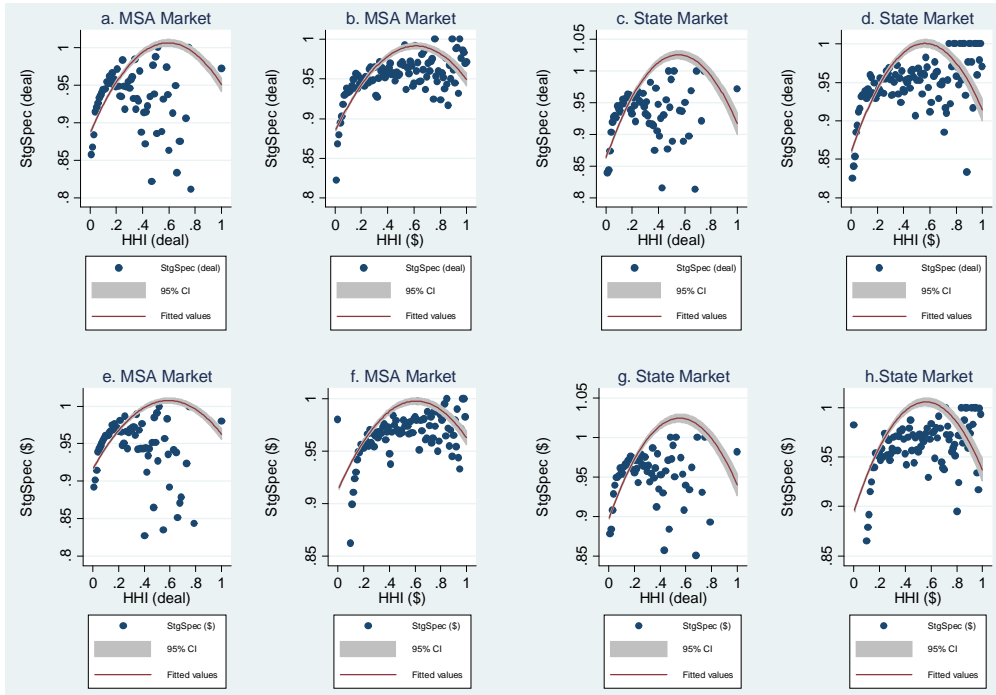
15

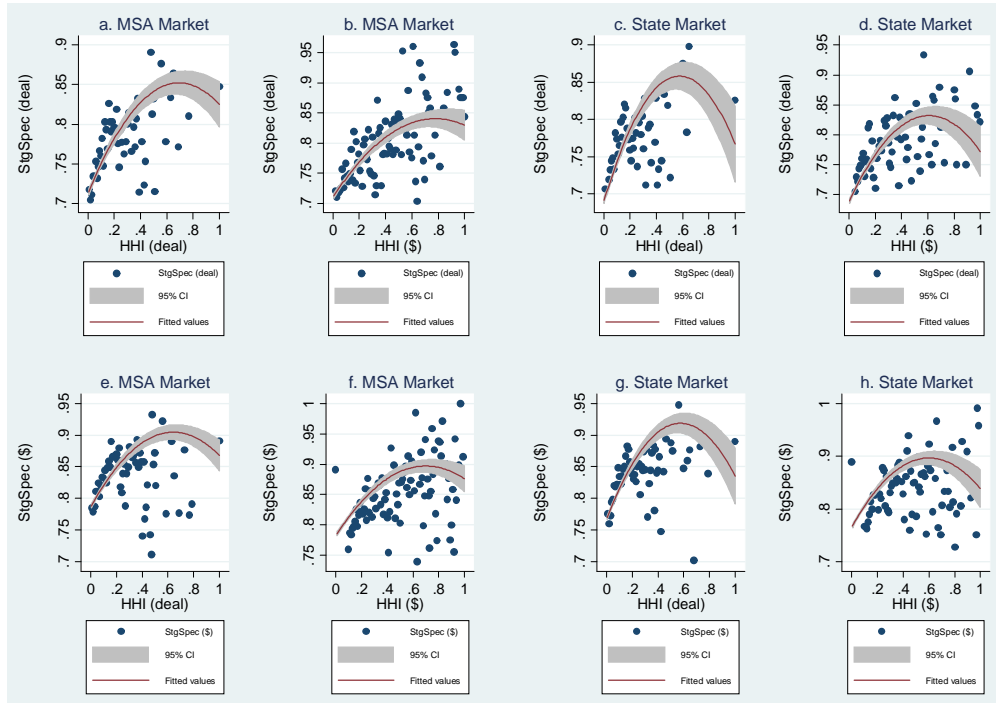Figure 3: Data description: Stage specialization versus market structure (HHI)

Figure 4: Data description: Stage specialization versus market structure (HHI), with low-volume VC firms removed

We estimate the quadratic model as specified in (5). If the effect of competition on specialization is non-monotonic and has the shape of an inverted U, we expect $\beta_1 > 0$ and $\beta_2 < 0$ over the range $hhi_{mt} \in [0, 1]$. Columns (2) and (3) confirm the non-monotonicity. In column (2), the linear and quadratic terms of the competition measures are the only explanatory variables and, in column (3), the VC market characteristics (e.g. experience, VC firm size, age) are included. $\beta_1 > 0$ and $\beta_2 < 0$ suggest the highest specialization level in the intermediately competitive market. The magnitudes of our estimates in column (3) with the inclusion of VC control variables are very similar to those in column (2). This is quite reassuring and our results are not likely driven by unobserved VC firm-specific factors.

As alluded to previously, the strong presence of low-volume VC firms may raise concerns. We test the robustness of our results by excluding inactive VC firms and low-volume markets. The results remain similar.[44]

4.3 Instrumental Variables Approach

A first-order concern with our findings in Table 2 is the omitted market-level variables that affect both specialization and the intensity of competition. Despite this concern, our results are not likely to be spurious because the omitted factors have to vary non-monotonically with market potential and a VC firm's stage specialization choice to generate the bias. However, it's still possible that firms in intermediately competitive markets may choose to specialize more for reasons unrelated to competition. To address such concerns, we employ an instrumental variables approach.

Our instruments consist of market-level demand shifters, as well as their squared counterparts. The identification assumption is that demand factors affect the intensity of competition by attracting entries or inducing exits and are otherwise assumed to be unrelated with VC firms' specialization decisions. We adopt demand shifters as identified by Gompers and Lerner (2000). Specifically, we use the average value-weighted industry book-to-market ratio, the logarithm of the VC firm inflow in the market, the logarithm of the cumulative VC firm inflow since 1975, and the logarithm of the number of deals in the market to proxy for investment opportunities, "money-chasing deals," and market size. As shown by Hochberg, Ljungqvist, and Lu (2010), these variables are highly correlated with entries of VC firms, therefore, affect the intensity of competition. Similar to these authors, we lag our demand variables by one year to account for deferred VC firm responses to market climate.[45]

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[44]Specifically, (i) we exclude VC firms from our analysis if the firm participated in fewer than five funding rounds in the past five years, (ii) we exclude VC firms that participated in fewer than 10 funding rounds in their lifetime, and (iii) we exclude low-volume markets with fewer than five deals in a given year. These all lead to the same findings as those presented in Table 2. We do not report these results in the paper but they are available upon request.

[45]The results are similar if we use un-lagged demand variables. Table 1 provides the summary statistics of the market-level demand variables. Other possible instruments, such as the market's gross domestic product,

Table 3 presents the results from the instrumental variables model based on various defini-tions of the market, stage specialization, and competition.[46] We identify a similar inverted-U re-lationship. The magnitude of our estimates suggests that VC firms are most specialized when the market is neither too concentrated nor too competitive. For example, based on Panel B column (1), maximum specialization is reached when the concentration ratio equals 1.07/(2*1.03)=0.52, that is, a market close to a (symmetric) duopoly. Consistent with this figure, Panel C column (1) suggests that the peak of specialization is reached when 1/nvc=1.28/(2*1.42)=0.45, that is, the number of VC firms equals 1/0.45=2.2.[47] These numbers are quite close to the peak of the inverted U curve in Figures 3 and 4.

4.4 Robustness checks

We report a number of robustness checks in Appendix A and they all indicate an inverted-U relationship. To address concerns about low-volume VC firms, columns (I) and (II) of Table A1 repeat our analysis after excluding VC firms that fund fewer than two deals in any market year, which effectively eliminates about 75% of the observations. Alternatively, we remove VC firms without at least 20 deals throughout the sample period in columns (III) and (IV). Finally, in columns (V) and (VI), we eliminate low-volume markets without at least five deals funded in a given year or at least 25 deals funded in a five-year window prior to the current year.

Next, we expand our market definition and perform the analysis based on a two-year time window (instead of the one-year time window currently used in our main specifications). This is intended to capture the idea that it may take more than one year for VC firms to build investment portfolios or to establish competitive presences. Table A2 in Appendix A presents the results. These are mostly quantitatively similar to those in Table 3. The quadratic terms are marginally significant or insignificant in a few specifications. This is not too surprising, since a more widely defined market could overstate the intensity of competition. Widening the time window causes more observations to cluster on the competitive side of the inverted-U curve (i.e., in the upward-sloping region) and this weakens the quadratic term.

Finally, VC firm syndication, that is, multiple VC firms co-investing in the same round, could potentially soften competition (Hong 2013). We perform two additional analyses: First, we use alternative measures of competition based on: (i) syndicate leaders and the amount raised by the leader in a given round and (ii) the number of inexperienced entrants, and second, we use the fraction of syndicated deals as an additional instrument. Our results remain quanti-tatively similar. We also look into additional specifications with higher-order polynomials. The

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population, number of new portfolio companies funded, and fraction of syndicated deals, explain little variation in the intensity of competition.

[46]In all specifications, we include firm market fixed effects, year dummies, and VC firm characteristics. The standard errors are corrected for correlations within markets.

[47]Our results based on the number of VC firms in a market are also robust to the exclusion of inactive VC firms. As defined by Hochberg, Ljungqvist, and Lu (2010), a VC firm is considered actively investing in the target market if it funded at least five deals in the past five years.

cubic terms are insignificant in many specifications. The Bayesian Information Criterion (BIC) suggests that higher-order polynomials do not improve the fit.[48]

4.5   Effect of Competition on Value

In our theoretical model, competition intensifies as the market grows and low-quality entrepreneurs are more likely to get funded. As a result, all VC firms are forced to offer higher utility to entrepreneurs (i.e., higher valuations). The effect is more pronounced among low-quality VC–EN pairs, that is, at the lower end of the market (see Figure B.6). The *differential* impact of competition (on high- and low-quality VC firms) is one of the key drivers of our results.

Empirically, one major challenge in testing such a mechanism is that quality is unobservable. Within the limitations of our data, we focus on two types of entrepreneurial companies, those that underwent an IPO and those that did not. It is conceivable that the average quality of a company that received an IPO is higher than that of a non-IPO company.[49] We expect the value received by the lower-quality entrepreneur (i.e., non-IPO companies) to increase more with competition than that of high-quality ones (i.e., IPO companies).

In this Section, we provide evidences consistent with the mechanism established in the model. Namely, (i) competition increases the pre-money valuations on average and (ii) even more for low quality than for high quality entrepreneurs.[50]

First, we regress the logarithm of company valuation in a given round on measures of competition while controlling for other determinants of valuation. We use the logarithm of cumulative investment a company received from all previous rounds to proxy for time-varying capital stock. We also include entrepreneur characteristics such as the development stage (e.g., seed/early) and the number of years elapsed since the first round. We use lead investor experience and lead investor size to control for the value added by VC firms.[51] As Gompers and Lerner (2000), we control for investment opportunities and money-chasing deals using the average value of the weighted book-to-market ratio of the company's industry and the logarithm of the number of deals in the market. Other time-invariant determinants of valuation are controlled for using a set of market fixed effects and year dummies. Our value analysis specifications closely mirror those of Gompers and Lerner (2000) and Hochberg, Ljungqvist, and Lu (2010).

Columns (1) and (2) of Table 4 display the results in the MSA and state markets, using various measures of competition. The effect of competition is significant with the expected

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[48]To economize on space, we do not report these results in this paper but they are available upon request.

[49]An IPO is a clear success and a good indicator for high quality, while other options (e.g. acquisitions) are less clear-cut. For example, acquisitions can sometimes be disguised failures and entrepreneurial companies may exit through a mergers and acquisitions simply because they have assets that an acquirer wants. In our sample, only 18% of the entrepreneurial companies received an IPO.

[50]VentureXpert database records post-round valuations and we subtract the round amount from the round value to recover pre-money valuation.

[51]A VC firm is considered a lead investor in a given round if it invests the largest amount in the company. In case of multiple lead investors, we use the maximum experience and size among leaders.

signs. For example, higher concentration (and less competition) in Panel A is associated with lower valuation received by the entrepreneur and a greater number of competitors in Panel C is associated with higher valuations.

One well-known problem with VentureXpert data is that the valuations are self-reported by VC firms and are missing for about 80% of the investment rounds. It is possible that the disclosure of valuations is strategic. For example, a company may choose not to disclose rounds with lower valuations than in previous rounds. To correct for such a selection bias, we adopt the procedure proposed by Hwang, Quigley, and Woodward (2005) and use an ordered probit model of seven events when a valuation may be disclosed.[52] As Hwang, Quigley, and Woodward (2005), we include the number of quarters lapsed since the most recent funding round, its interaction with the company's development status, and stock market capitalization in the selection equation. We construct the inverse Mill's ratio from the ordered probit model for each investment round and include it in the value analysis. Our choices of the ordered events and the control and excluded variables closely follow those of Hwang, Quigley, and Woodward (2005) and Hochberg, Ljungqvist, and Lu (2010). The standard errors in the selection-corrected value analysis are computed based on 300 bootstraps.

Columns (3) and (4) of Table 4 display the results from the selection-corrected models. They are consistent with the idea that competition indeed increases the valuations received by entrepreneurs. The inverse Mill's ratio is highly significant in all specifications, suggesting the existence of selection bias. The coefficients are generally more precisely estimated, with magnitudes similar to those of linear models. The effect of competition is quite substantial. On average, a 1% increase in the HHI (based on deal share) is associated with a 0.23% decrease in value received by an entrepreneur in an MSA market and a 0.21% decrease in a state market.[53]

Next, we use similar specifications to investigate the *differential* effect of competition on valuation. We divide the sample into IPO and non-IPO companies and perform our analysis on each sub-sample respectively. Columns (1) to (4) of Table 5 report estimates obtained from linear models, while columns (5) to (8) are selection corrected.[54]

Among low-quality entrepreneurs (i.e., ipo=0), increasing concentration is associated with lower valuation, while such an effect is much smaller or statistically close to zero among high-quality entrepreneurs (i.e., ipo=1). For example, columns (1) and (2) of Panel A of Table 5 suggests that a 1% increase in the HHI is associated with a 0.25% decrease in the value put on low-quality entrepreneurs, all else being equal, while the effect is insignificant on high-quality entrepreneurs. Coefficients from selection-corrected models are more precisely estimated. Columns (5) and (6) of Panel A indicate that a 1% increase in concentration is associated with a

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[52]These events are 1) a shut-down, 2) no event, 3) the company receives a new funding round without disclosing value, 4) the company receives a new funding round and discloses valuation, 5) the company is acquired without disclosing valuation, 6) the company is acquired with the valuation disclosed, and 7) an IPO.

[53]The full set of coefficients for the specifications in Table 4 are presented in Table A3 Appendix A.

[54]Table A4 in Appendix A presents the full set of coefficients.

0.23% decrease in value for non-IPO companies and 0.16% for IPO companies. We acknowledge that the effects of competition on IPO and non-IPO companies are not statistically different in columns (7) and (8) of Panel A. Nevertheless, the magnitudes of the estimates seem to point in the same direction.

Overall, our analyses based on the IPO and non-IPO sub-samples indicate that values received by low-quality entrepreneurs increase faster with competition than for high-quality entrepreneurs. This is consistent with our intuition that $u^*(i)$ increases more at the low end of the market than at the high end when competition intensifies.

5   Conclusion

We investigate the effect of competition on VC firms' incentives to specialize. In particular, we focus our attention on stage specialization.

We develop a theoretical market equilibrium model that captures many salient features of the VC market. In equilibrium, a high-quality VC firm matches with a high-quality entrepreneur and the equilibrium utility paid to the entrepreneur is an increasing function of entrepreneur quality. Competition (entry of low-expertise VC firms) creates two opposing forces on a VC firm's incentives to invest resources in stage specialization. On the one hand, it increases the entrepreneur's equilibrium utility, with greater impact at the lower end of the market. This gives the VC firms incentives to invest relatively more resources in the more specialized stage (i.e., the stage higher up the quality ladder), resulting in a higher degree of specialization. On the other hand, competition flattens the equilibrium utility schedule, with a bigger impact at the bottom of the quality ladder. Hence, it becomes cheaper for VC firms to improve their ranking and match with better entrepreneurs in any stage. VC firms closer to the bottom of the quality ladder have stronger incentives for such improvements and specialization decreases.

These two opposing forces hint at a non-monotonic relationship that we test using data from VentureXpert. Our empirical results reveal an inverted U-shaped relationship between the intensity of competition and stage specialization. Contrary to conventional wisdom, our results suggest that stronger competition may not always lead to higher specialization.

The significance of our results is threefold. First, we provide new insights on the determinants of specialization. While many papers document that specialization is closely related with firm performance, few study how specialization arises in the first place. Second, we learn more about how a VC firm's internal organizational structure depends on market forces. So far, the literature has focused more on the impact of VC firm characteristics on specialization and has left the impact of market structure largely unexplored. Finally, our main result—that a larger market can discourage specialization in the VC market—may be applied to other markets that exhibit two-sided vertical heterogeneity, such as the markets for professionals and academics.

Table 1. Summary Statistics

		MSA Market		State Market	
		Mean	Std Dev	Mean	Std Dev
Panel A: Market Specific VC Characteristics					
stgspec$_{fmt}$	stage specialization based on deal share	0.92	0.19	0.90	0.20
dstgspec$_{fmt}$	stage specialization based on dollar share	0.94	0.15	0.92	0.17
cumexp$_{fmt}$	VC's cumulative experience in market m	5.59	12.9	7.99	20.6
age$_{fmt}$	no. years elapsed since first invest in m	4.22	5.35	4.60	5.60
N		73283		64751	
Panel B: VC Characteristics					
cumexp$_{ft}$	VC's cumulative experience	63.1	133	61.9	132
nfund$_{ft}$	number of fund under management	1.73	1.18	1.72	1.17
ngeo$_{ft}$	number of geographical market invested	4.04	3.74	3.13	2.72
nind$_{ft}$	number of industry invested	2.17	2.60	3.08	4.57
size$_{ft}$	VC's $ under management	66,841	201,206	65,608	199,132
N		15967		16345	
Panel C: Competition Measures					
hhi$_{mt}$	hhi based on deal share	0.40	0.34	0.30	0.29
dhhi$_{mt}$	hhi based on the imputed dollar share	0.46	0.34	0.37	0.31
nvc$_{mt}$	number of VC firm	13.0	29.2	20.0	45.1
N		7345		4196	
Panel D: Market Characteristics					
ndl$_{mt}$	number of deals	7.69	23.8	14.2	48.6
avgbmr$_{mt}$	average industry book to market ratio	0.33	0.15	0.34	0.15
vcinflow$_{mt}$	total amount of VC inflow	50,715	263,481	91,048	525,615
cuminflow$_{mt}$	cumulative VC inflow since 1975	345,768	1,457,298	635,290	2,995,341
N		7345		4196	

Table 2. The descriptive relationship between competition on stage specialization

Dep Var	MSA Market						State Market					
	Stage Spec (deal)			Stage Spec ($)			Stage Spec (deal)			Stage Spec ($)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Panel A												
log(hhi)	0.03***			0.02***			0.03***			0.02***		
	(0.00)			(0.00)			(0.00)			(0.00)		
hhi		0.13***	0.15***		0.10***	0.12***		0.14***	0.21***		0.11***	0.16***
		(0.03)	(0.03)		(0.03)	(0.02)		(0.04)	(0.04)		(0.03)	(0.03)
hhi²		-0.09***	-0.10***		-0.07***	-0.08***		-0.12***	-0.17***		-0.09***	-0.13***
		(0.03)	(0.03)		(0.02)	(0.02)		(0.03)	(0.04)		(0.03)	(0.03)
Adj. R²	0.02	0.02	0.10	0.02	0.01	0.09	0.02	0.02	0.08	0.02	0.01	0.07
Panel B												
log(dhhi)	0.02***			0.02***			0.02***			0.02***		
	(0.00)			(0.00)			(0.00)			(0.00)		
dhhi		0.11***	0.12***		0.09***	0.10***		0.13***	0.17***		0.09***	0.12***
		(0.03)	(0.02)		(0.02)	(0.02)		(0.03)	(0.03)		(0.03)	(0.03)
dhhi2		-0.07***	-0.08***		-0.06***	-0.07***		-0.09***	-0.12***		-0.07***	-0.09***
		(0.02)	(0.02)		(0.02)	(0.02)		(0.03)	(0.03)		(0.02)	(0.02)
Adj. R²	0.02	0.02	0.10	0.02	0.01	0.09	0.02	0.02	0.08	0.02	0.01	0.07
Panel C												
log(1/nvc)	0.04***			0.03***			0.04***			0.03***		
	(0.00)			(0.00)			(0.00)			(0.00)		
1/nvc		0.19***	0.22***		0.14***	0.16***		0.22***	0.29***		0.16***	0.22***
		(0.03)	(0.03)		(0.02)	(0.02)		(0.04)	(0.04)		(0.03)	(0.03)
1/nvc²		-0.13***	-0.15***		-0.10***	-0.11***		-0.17***	-0.22***		-0.12***	-0.17***
		(0.02)	(0.02)		(0.02)	(0.02)		(0.03)	(0.04)		(0.03)	(0.03)
Adj. R²	0.02	0.02	0.10	0.02	0.01	0.09	0.02	0.02	0.08	0.02	0.01	0.07
VC char	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y
Obs/no. vc	73,283/2,231						64,751/2,280					

Note: ***1%, **5% and *10%. All specifications include VC-market specific fixed effects and year dummies. The dependant variable is VC firm's stage specicialization measure in a given market year computed based on deal share or dollar share. Market is either state-industry or MSA-industry combinations. Standard errors are clustered at market level to account for the unobserved correlation within market. VC characteristics include: $\log(1+\mathrm{cumexp}_{imt})$, $\log(\mathrm{age}_{imt})$, $\log(1+\mathrm{cumexp}_{it})$, $\log(\mathrm{size}_{it})$, nfund_{it}, ngeo_{it}, nind_{it}.

Table 3. The effect of competition on specialization.

Dep Var	MSA Market		State Market	
	stgspec(deal)	stgspec($)	stgspec(deal)	stgspec($)
	(1)	(2)	(3)	(4)
Panel A				
$\widehat{hhi}$	1.35***	1.02***	1.78***	1.45***
	(0.23)	(0.18)	(0.43)	(0.35)
$\widehat{hhi^2}$	-1.35***	-1.03***	-2.04***	-1.65***
	(0.31)	(0.24)	(0.64)	(0.51)
Panel B				
$\widehat{dhhi}$	1.07***	0.81***	1.43***	1.16***
	(0.24)	(0.19)	(0.36)	(0.29)
$\widehat{dhhi^2}$	-1.03***	-0.79***	-1.58***	-1.27***
	(0.32)	(0.25)	(0.53)	(0.41)
Panel C				
$\widehat{1/nvc}$	1.28***	0.97***	1.79***	1.48***
	(0.23)	(0.18)	(0.45)	(0.36)
$\widehat{1/nvc^2}$	-1.42***	-1.08***	-2.21***	-1.83***
	(0.31)	(0.24)	(0.71)	(0.57)
No. vc-mkt	18,629		15,425	
Obs/no. vc	73,283/2231		64,751/2280	

Note: ***1%, **5% and *10%. Hat represents the instrumented variable. The dependent variable is stage specialization measure based on deal share or the imputed dollar share. hhi is the concentration ratio based on deal share and dhhi is the concentration ratio based on the imputed dollar amount share. nvc is the number of VCs in the market. All specifications include VC-market specific fixed effects and year dummies and VC characteristics including $\log(1+\text{cumexp}_{fmt})$,$\log(\text{age}_{fmt})$,$\log(1+\text{cumexp}_{ft})$,$\log(\text{size}_{ft})$,$\text{nfund}_{ft}$, ngeo_{ft},nind_{ft}. The market is MSA-industry or state-industry combinations. Standard errors are clustered at market level to account for the unobserved correlation within market. The instruments include: the logged vc inflow in market, average value weighted book to market ratio, the logged total number of deals in the market, the logged cumulative vc inflow since 1975 as well as their squared counter parts.

Table 4. The Effects of Competition on Valuation

	MSA	State	MSA Selection	State Selection
	(1)	(2)	(3)	(4)
Panel A				
log(hhi)	-0.19***	-0.16***	-0.23***	-0.21***
	(0.03)	(0.05)	(0.03)	(0.05)
inv mill's ratio	-	-	0.15***	0.15***
	-	-	(0.01)	(0.02)
Adj R^2	0.43	0.42	-	-
Panel B				
log(dhhi)	-0.06**	-0.05	-0.09***	-0.08*
	(0.03)	(0.04)	(0.03)	(0.04)
inv mill's ratio	-	-	0.15***	0.15***
	-	-	(0.01)	(0.02)
Adj R^2	0.38	0.38	-	-
Panel C				
log(nvc)	0.23***	0.26***	0.21***	0.21***
	(0.04)	(0.06)	(0.03)	(0.05)
inv mill's ratio	-	-	0.15***	0.15***
	-	-	(0.01)	(0.01)
Adj R^2	0.39	0.38	-	-
No mkt	501	217	501	217
Obs	15,482	15,557	15,482	15,557

Note: ***1%, **5% and *10%. Dependent variable is the logged value received by entrepreneur prior to a funding round. All specifications include market fixed effects, year dummies and control variables. Standard errors in the fixed effects models are clustered at market level and in the selection corrected models are computed based on 300 bootstraps. log(hhi) is the concentration ratio based on deal share and log(dhhi) is based the imputed dollar share. log(nvc) is the logged number of VC firms in the market. Control variables are entrepreneur characteristics including: the logged cumulative VC investment on the company before the current round, indicators for early/seed stage, the second and the third funding round, the number of years elapsed since the company received the first VC investment; lead investor characteristics including: the logged lead investor size, the logged number of funding rounds the lead investor participated; market characteristics including: the logged number of deals in the market, the logged total vc investment in the market, the valued weighted average book to market ratio. In the selection corrected model, an ordered probit model is estimated based on the following events: 1) shut down, 2) no event, 3) company receives a new funding round without disclosing value, 4) company receives a new funding round and discloses valuation, 5) company is acquired without disclosing valuation, 6) company is acquired with the valuation disclosed, 7) IPO. The excluded variables are the number of quarters elapsed since the most recent funding round, its interaction with company's development status, stock market capitalization. The ordered model is used to calculate the inverse mill's ratio and then included in the value regression. Our selection model and specification closely follow Hwang, Quigley and Woodward (2005). Appendix A3 presents the full set of estimates.

Table 5. Differential Effect of Competition on Valuation

	MSA		State		MSA Selection		State Selection	
	ipo=0	ipo=1	ipo=0	ipo=1	ipo=0	ipo=1	ipo=0	ipo=1
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A								
log(hhi)	-0.25***	-0.07	-0.24***	-0.09	-0.23***	-0.16**	-0.19***	-0.18**
	(0.04)	(0.06)	(0.06)	(0.08)	(0.04)	(0.06)	(0.06)	(0.08)
inv mill's ratio	-	-	-	-	0.05***	0.31***	0.05***	0.31***
	-	-	-	-	(0.01)	(0.04)	(0.01)	(0.03)
Adj R^2	0.40	0.44	0.39	0.43	-	-	-	-
Panel B								
log(dhhi)	-0.12***	0.07	-0.09*	0.06	-0.12***	-0.03	-0.08*	-0.04
	(0.03)	(0.05)	(0.05)	(0.06)	(0.03)	(0.05)	(0.04)	(0.06)
inv mill's ratio	-	-	-	-	0.05***	0.31***	0.05***	0.31***
	-	-	-	-	(0.01)	(0.04)	(0.01)	(0.03)
Adj R^2	0.40	0.44	0.39	0.43	-	-	-	-
Panel C								
log(nvc)	0.26***	0.10	0.28***	0.13	0.24***	0.08	0.22***	0.09
	(0.04)	(0.07)	(0.06)	(0.09)	(0.04)	(0.06)	(0.06)	(0.08)
inv mill's ratio	-	-	-	-	0.05***	0.31***	0.05***	0.31***
	-	-	-	-	(0.01)	(0.04)	(0.01)	(0.03)
Adj R^2	0.40	0.44	0.39	0.43	-	-	-	-
No mkt	472	234	208	143	472	234	208	143
Obs	11,551	3,931	11,607	3,950	11,551	3,931	11,607	3,950

Note: ***1%, **5% and *10%. Dependent variable is the logged value received by entrepreneur prior to a funding round. All specifications include market fixed effects, year dummies and control variables. Standard errors in the fixed effects models are clustered at market level and in the selection corrected models are computed based on 300 bootstraps. log(hhi) is the competition measure based on deal share and log(dhhi) is based on the imputed dollar share. log(nvc) is the logged number of VC firms in the market. Control variables are entrepreneur characteristics including: the logged cumulative VC investment on the company before the current round, indicators for early/seed stage, the second and the third funding round, the number of years elapsed since the company received the first VC investment; lead investor characteristics including: the logged lead investor size, the logged number of funding rounds the lead investor participated; market characteristics including: the logged number of deals in the market, the logged total vc investment in the market, the valued weighted average book to market ratio. In the selection corrected model, an ordered probit model is estimated based on the following events: 1) shut down, 2) no event, 3) company receives a new funding round without disclosing value, 4) company receives a new funding round and discloses valuation, 5) company is acquired without disclosing valuation, 6) company is acquired with the valuation disclosed, 7) IPO. The excluded variables are the number of quarters elapsed since the most recent funding round, its interaction with company's development status, stock market capitalization. The ordered model is used to calculate the inverse mill's ratio and then included in the value regression. Our selection model and specification closely follow Hwang, Quigley and Woodward (2005). Appendix A4 presents the full set of estimates.

A Appendix: Robustness Checks

Table A1. Additional Robustness Checks to the Non-Monotonic Relationship

	MSA Market						State Market					
	(I)	(II)	(III)	(IV)	(V)	(VI)	(I)	(II)	(III)	(IV)	(V)	(VI)
Panel A												
$\widehat{hhi}$	2.74***	1.98***	1.31***	1.00***	7.41***	5.59***	2.49***	2.30***	1.79***	1.46***	6.07***	4.55***
	(0.78)	(0.59)	(0.22)	(0.17)	(1.78)	(1.43)	(0.85)	(0.67)	(0.44)	(0.36)	(1.58)	(1.25)
$\widehat{hhi^2}$	-2.77**	-1.97**	-1.30***	-1.00***	-35.13***	-26.44***	-2.79*	-2.55**	-2.02***	-1.66***	-26.33***	-19.17***
	(1.17)	(0.89)	(0.29)	(0.23)	(10.68)	(8.67)	(1.51)	(1.15)	(0.65)	(0.52)	(8.83)	(6.91)
Panel B												
$\widehat{dhhi}$	1.68***	1.24***	1.06***	0.81***	3.29***	2.47***	1.59***	1.52***	1.45***	1.18***	3.24***	2.55***
	(0.45)	(0.37)	(0.23)	(0.18)	(0.85)	(0.68)	(0.58)	(0.46)	(0.37)	(0.30)	(0.78)	(0.62)
$\widehat{dhhi^2}$	-1.36**	-0.97*	-1.02***	-0.79***	-7.85***	-5.83**	-1.64*	-1.54**	-1.58***	-1.28***	-6.78***	-5.25***
	(0.63)	(0.52)	(0.32)	(0.25)	(2.97)	(2.37)	(0.98)	(0.77)	(0.53)	(0.42)	(2.18)	(1.72)
Panel C												
$\widehat{1/nvc}$	2.65***	1.91***	1.22***	0.92***	9.63***	7.26***	2.52***	2.37***	1.82***	1.51***	10.74***	8.24***
	(0.80)	(0.61)	(0.21)	(0.17)	(1.99)	(1.56)	(0.91)	(0.74)	(0.46)	(0.37)	(2.88)	(2.26)
$\widehat{1/nvc^2}$	-2.72**	-1.91**	-1.33***	-1.01***	-78.45***	-58.90***	-3.03*	-2.85**	-2.23***	-1.85***	-79.09***	-60.05***
	(1.17)	(0.88)	(0.29)	(0.22)	(21.73)	(17.23)	(1.78)	(1.41)	(0.72)	(0.58)	(28.02)	(21.74)
Obs	18,315		67,486		50,378		19,613		58,702		51,025	

Note: ***1%, **5% and *10%. Hat represents the instrumented variables. All specifications include VC-market specific fixed effects, year dummies and VC market characteristics including $\log(1+\text{cumexp}_{imt})$,$\log(\text{age}_{imt})$,$\log(1+\text{cumexp}_{it})$,$\log(\text{size}_{it})$,$\text{nfund}_{it}$, ngeo_{it}, nind_{it}. Standard errors are clustered at market level to account for the unobserved correlation within market. The instruments include: the logged vc inflow in market, average value weighted book to market ratio, the logged total number of deals in the market as well as their squared counter parts. Summary statistics of instruments are reported in Panel D of Table 1. Dependant variables in specifications (I),(III),(V) are specialization measure based on deal share stgspec$_{fmt}$. Dependant variables in specifications (II),(IV),(VI) are specialization measure based on the imputed dollar shares dstgspec$_{fmt}$. Specifications (I) and (II) exclude VC firms who invest in less than two rounds in any given market year. Specification (III) and (IV) excludes VC firms who invest in less than 20 deals throughout the sample period. Specification (V) and (VI) excludes low volume markets, i.e markets with less than 25 deals funded in a five years window prior to the current calendar year and markets with less than 5 deals in a given year.

Table A2. Effect of Competition on Specialization in Two Years Window

	MSA Market		State Market	
	stgspec(deal)	stgspec(dollar)	stgspec(deal)	stgspec(dollar)
	(I)	(II)	(III)	(IV)
Panel A				
$\widehat{hhi}$	1.21***	0.85**	1.72***	1.32***
	(0.44)	(0.38)	(0.52)	(0.44)
$\widehat{hhi^2}$	-1.15**	-0.74*	-1.94***	-1.37**
	(0.52)	(0.44)	(0.72)	(0.61)
Panel B				
$\widehat{dhhi}$	0.89***	0.60**	0.89***	0.66**
	(0.28)	(0.24)	(0.30)	(0.27)
$\widehat{dhhi^2}$	-0.72**	-0.43	-0.79**	-0.50
	(0.31)	(0.27)	(0.40)	(0.35)
Panel C				
$\widehat{1/nvc}$	1.06**	0.76*	1.55***	1.25***
	(0.50)	(0.44)	(0.49)	(0.43)
$\widehat{1/nvc^2}$	-1.08*	-0.71	-1.92**	-1.45**
	(0.64)	(0.55)	(0.78)	(0.67)
Obs	45,232		39,599	

Note: ***1%, **5% and *10%. Hat represents the instrumented variable. The dependent variable is stage specialization measure based on deal share or the imputed dollar share. hhi is the competition measure based on deal share and dhh is the competition measure based on the imputed dollar amount share. nvc is the number of VCs in the market. All specifications include VC-market specific fixed effects and year dummies and VC characteristics including $\log(1+\text{cumexp}_{fmt})$,$\log(\text{age}_{fmt})$,$\log(1+\text{cumexp}_{ft})$,$\log(\text{size}_{ft})$,$\text{nfund}_{ft}$, ngeo_{ft},nind_{ft}. The market is MSA-industry or state-industry combinations. Standard errors are clustered at market level to account for the unobserved correlation within market. The instruments include: the logged vc inflow in market, average value weighted book to market ratio, the logged total number of deals in the market, the logged cumulative vc inflow since 1975 as well as their squared counter parts.

Table A3. Full set of estimates in Table 4

Dep var: log(value)	MSA Market			State Market			MSA Market Selection			State Market Selection		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Competition Measures												
log(hhi)	-0.19***			-0.16***			-0.23***			-0.21***		
	(0.03)			(0.05)			(0.03)			(0.05)		
log(dhhi)		-0.06**			-0.05			-0.09***			-0.08*	
		(0.03)			(0.04)			(0.03)			(0.04)	
log(nvc)			0.23***			0.26***			0.21***			0.21***
			(0.04)			(0.06)			(0.03)			(0.05)
Company Characteristics												
log(cum vc)	0.46***	0.17***	0.17***	0.45***	0.17***	0.17***	0.44***	0.44***	0.44***	0.44***	0.44***	0.43***
	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
early/seed	-0.75***	-0.73***	-0.73***	-0.75***	-0.73***	-0.73***	-0.75***	-0.76***	-0.76***	-0.75***	-0.76***	-0.75***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
second round	-3.02***	-0.57***	-0.56***	-2.99***	-0.57***	-0.57***	-2.91***	-2.92***	-2.91***	-2.87***	-2.89***	-2.87***
	(0.15)	(0.03)	(0.03)	(0.16)	(0.04)	(0.04)	(0.15)	(0.15)	(0.15)	(0.16)	(0.16)	(0.16)
third round	-3.07***	-0.29***	-0.28***	-3.03***	-0.29***	-0.29***	-2.93***	-2.95***	-2.93***	-2.89***	-2.91***	-2.88***
	(0.17)	(0.03)	(0.03)	(0.19)	(0.03)	(0.03)	(0.17)	(0.17)	(0.17)	(0.19)	(0.19)	(0.19)
age	0.01	-0.02**	-0.02**	0.01	-0.02*	-0.02*	0.01	0.01	0.01	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Lead Investor Characteristics												
log(size)	0.05***	0.05***	0.06***	0.05***	0.06***	0.06***	0.05***	0.05***	0.05***	0.05***	0.05***	0.05***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
log(experience)	-0.04***	-0.04***	-0.04***	-0.04***	-0.04***	-0.04***	-0.04***	-0.03***	-0.04***	-0.04***	-0.04***	-0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Market Characteristics												
log(no. deal)	-0.10***	-0.13***	-0.18***	-0.12***	-0.17***	-0.21***	-0.12***	-0.09***	-0.13***	-0.14***	-0.12***	-0.15***
	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)
log(vc inflow)	0.04	0.15***	0.09*	0.08	0.19***	0.10*	0.02	0.06	0.00	0.05	0.09*	0.03
	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)
avg bmr	-1.08***	-1.09***	-1.09***	-1.04***	-1.03***	-1.04***	-1.21***	-1.22***	-1.24***	-1.16***	-1.16***	-1.19***
	(0.17)	(0.18)	(0.18)	(0.17)	(0.20)	(0.19)	(0.17)	(0.18)	(0.18)	(0.18)	(0.18)	(0.18)
Constant	8.26***	7.46***	7.73***	7.63***	6.84***	7.19***	8.33***	8.23***	8.50***	7.70***	7.67***	7.96***
	(0.44)	(0.48)	(0.49)	(0.43)	(0.51)	(0.51)	(0.44)	(0.44)	(0.44)	(0.44)	(0.45)	(0.45)
inv mill's ratio	-	-	-	-	-	-	0.15***	0.15***	0.15***	0.15***	0.15***	0.15***
	-	-	-	-	-	-	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Obs		15,482			15,557			15,482			15,557	
Adj R2	0.43	0.38	0.39	0.42	0.38	0.38	-	-	-	-	-	-

Note: ***1%, **5% and *10%. Dependent variable is the logged value received by entrepreneur prior to a funding round. All specifications include market fixed effects, year dummies and control variables. Standard errors in the fixed effects models are clustered at market level and in the selection corrected models are computed based

on 300 bootstraps. log(hhi) is the competition measure based on deal share and log(dhhi) is based the imputed dollar share. log(nvc) is the logged number of VC firms in the market. log(cum VC $) is the logged cumulative VC investment on the company before the current round, early/seed is an indicator for early/seed stage projects, second and third round are indicators for the second and the third funding round, age is the number of years elapsed since the company received the first VC investment, log(size) is the logged cumulative investment the lead investor made, log(experience) is the logged number of funding rounds the lead investor participated, log(no. deal) is the logged number of deals in the market, log(vc inflow) is the logged total vc investment in the market, avgbmr is the valued weighted average book to market ratio in the industry year. In the selection corrected model, an ordered probit model is estimated based on the following events: 1) shut down, 2) no event, 3) company receives a new funding round without disclosing value, 4) company receives a new funding round and discloses valuation, 5) company is acquired without disclosing valuation, 6) company is acquired with the valuation disclosed, 7) IPO. The excluded variables are the number of quarters elapsed since the most recent funding round, its interaction with company's development status, stock market capitalization. The ordered model is used to calculate the inverse mill's ratio and then included in the value regression. Our selection model and specification closely follow Hwang, Quigley and Woodward (2005).

Table A4. Full set of estimates in Table 5

	MSA Market Selection Model						State Market Selection					
Dep var: log(value)	(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
	ipo=0	ipo=1	ipo=0	ipo=1	ipo=0	ipo=1	ipo=0	ipo=1	ipo=0	ipo=1	ipo=0	ipo=1
Competition Measure												
log(hhi)	-0.23***	-0.16**					-0.19***	-0.18**				
	(0.04)	(0.06)					(0.06)	(0.08)				
log(dhhi)			-0.12***	-0.03					-0.08*	-0.04		
			(0.03)	(0.05)					(0.04)	(0.06)		
log(nvc)					0.24***	0.08					0.22***	0.09
					(0.04)	(0.06)					(0.06)	(0.08)
Company Characteristics												
log(cum vc)	0.45***	0.30***	0.45***	0.30***	0.45***	0.30***	0.44***	0.29***	0.44***	0.29***	0.44***	0.29***
	(0.02)	(0.04)	(0.02)	(0.04)	(0.02)	(0.04)	(0.02)	(0.04)	(0.02)	(0.04)	(0.02)	(0.04)
early/seed	-0.64***	-0.91***	-0.64***	-0.91***	-0.64***	-0.91***	-0.64***	-0.92***	-0.64***	-0.93***	-0.64***	-0.92***
	(0.04)	(0.07)	(0.04)	(0.07)	(0.04)	(0.07)	(0.04)	(0.07)	(0.04)	(0.07)	(0.04)	(0.07)
second round	-2.91***	-1.87***	-2.93***	-1.87***	-2.91***	-1.86***	-2.88***	-1.83***	-2.90***	-1.83***	-2.87***	-1.82***
	(0.16)	(0.28)	(0.16)	(0.28)	(0.16)	(0.28)	(0.15)	(0.29)	(0.15)	(0.29)	(0.15)	(0.29)
third round	-2.95***	-1.72***	-2.97***	-1.72***	-2.95***	-1.71***	-2.91***	-1.69***	-2.93***	-1.69***	-2.90***	-1.67***
	(0.18)	(0.31)	(0.18)	(0.31)	(0.18)	(0.31)	(0.18)	(0.32)	(0.18)	(0.32)	(0.18)	(0.32)
age	-0.02*	0.00	-0.02**	0.00	-0.02**	0.00	-0.02*	-0.00	-0.02*	-0.00	-0.02*	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Lead Investor Characteristics												
log(size)	0.04***	0.06***	0.04***	0.06***	0.04***	0.06***	0.04***	0.07***	0.04***	0.07***	0.04***	0.07***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
log(experience)	-0.00	-0.11***	-0.00	-0.11***	-0.00	-0.11***	0.00	-0.12***	0.00	-0.12***	0.00	-0.12***
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)
Market Characteristics												
log(no. deal)	-0.09**	-0.09	-0.07*	-0.05	-0.10***	-0.06	-0.13***	-0.03	-0.12***	-0.00	-0.15***	-0.01
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.08)	(0.04)	(0.08)	(0.04)	(0.08)
log(vc inflow)	0.03	0.01	0.06	0.05	0.01	0.01	0.09*	-0.02	0.12**	0.02	0.06	-0.02
	(0.04)	(0.08)	(0.04)	(0.08)	(0.04)	(0.08)	(0.05)	(0.09)	(0.05)	(0.09)	(0.05)	(0.10)
avg bmr	-1.21***	-0.47	-1.21***	-0.51	-1.23***	-0.55	-1.16***	-0.44	-1.16***	-0.47	-1.17***	-0.51
	(0.19)	(0.38)	(0.20)	(0.38)	(0.19)	(0.38)	(0.21)	(0.44)	(0.22)	(0.45)	(0.21)	(0.44)
constant	7.32***	8.30***	7.30***	8.18***	7.47***	8.51***	7.73***	8.36***	7.72***	8.31***	7.99***	8.67***
	(0.61)	(0.81)	(0.64)	(0.78)	(0.63)	(0.82)	(0.54)	(0.77)	(0.53)	(0.78)	(0.54)	(0.79)
Inv mill's ratio	0.05***	0.31***	0.05***	0.31***	0.05***	0.30***	0.05***	0.31***	0.05***	0.31***	0.05***	0.31***
	(0.01)	(0.04)	(0.01)	(0.04)	(0.01)	(0.04)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)
obs	11,551	3,931	11,551	3,931	11,551	3,931	11,607	3,950	11,607	3,950	11,607	3,950

Note: ***1%, **5% and *10%. Dependent variable is the logged value received by entrepreneur prior to a funding round. All specifications include market fixed effects, year dummies and control variables. Standard errors in the fixed effects models are clustered at market level and in the selection corrected models are computed based

on 300 bootstraps. log(hhi) is the competition measure based on deal share and log(dhhi) is based the imputed dollar share. log(nvc) is the logged number of VC firms in the market. log(cum VC \$) is the logged cumulative VC investment on the company before the current round, early/seed is an indicator for early/seed stage projects, second and third round are indicators for the second and the third funding round, age is the number of years elapsed since the company received the first VC investment, log(size) is the logged cumulative investment the lead investor made, log(experience) is the logged number of funding rounds the lead investor participated, log(no. deal) is the logged number of deals in the market, log(vc inflow) is the logged total vc investment in the market, avgbmr is the valued weighted average book to market ratio in the industry year. In the selection corrected model, an ordered probit model is estimated based on the following events: 1) shut down, 2) no event, 3) company receives a new funding round without disclosing value, 4) company receives a new funding round and discloses valuation, 5) company is acquired without disclosing valuation, 6) company is acquired with the valuation disclosed, 7) IPO. The excluded variables are the number of quarters elapsed since the most recent funding round, its interaction with company's development status, stock market capitalization. The ordered model is used to calculate the inverse mill's ratio and then included in the value regression. Our selection model and specification closely follow Hwang, Quigley and Woodward (2005).

B Appendix: Theoretical Model

B.1 VC Market Equilibrium

We derive the optimal contract (equity share) for a given VC-EN relationship in stage s and then we embed the pair into the market and study the properties of the market equilibrium.[55]

B.1.1 Optimal Effort and Contract in a Given VC-EN Pair

We begin by solving the entrepreneur's problem. For a given match quality Ω and equity shares λ, the entrepreneur chooses effort e to maximize his expected utility:

$$\max_{\{e\}} U(e, \lambda, \Omega) = \lambda \pi(\Omega) e - \frac{e^2}{2}. \tag{B.6}$$

The entrepreneur's optimal effort is thus given by

$$e^* = \lambda \pi(\Omega). \tag{B.7}$$

To ensure that $\text{Prob}[Y = 1|e^*] = e^* < 1$, we assume that $\pi(\Omega) < 1$ for any possible match quality Ω. The VC firm can indirectly control the entrepreneur's effort e^* by adjusting the equity share λ. The VC firm now chooses λ to maximize its expected stage s profit subject to the participation and incentive compatibility constraints of the entrepreneur.

$$\overline{\Pi}(u, \Omega) \equiv \max_{\{\lambda\}} q\left((1 - \lambda)\pi(\Omega)e^* - rK\right) \tag{B.8}$$

subject to:

$$\lambda \pi(\Omega) e^* - \frac{e^*}{2} \geq u, \tag{B.9}$$

where $e^* = \lambda \pi(\Omega)$ and u is the entrepreneur's reservation utility (outside option).

The expected utility of the entrepreneur, after we substitute e^* into his utility function, is $U = \lambda^2(\pi(\Omega))^2/2$. Then, if the individual rationality constraint of the entrepreneur is binding, the VC will choose the following equity stake

$$\lambda = \frac{\sqrt{2u}}{\pi(\Omega)}$$

to ensure that the entrepreneur's expected utility is u. After we substitute λ into e^* we obtain the equilibrium effort of the entrepreneur: $e^* = \sqrt{2u}$, which is the probability of success in stage s. To simplify the analysis further we set the cost of capital r equal to zero.

---

[55]To simplify our notation, we henceforth suppress the subscript sij when referring to an arbitrary EN-VC pair in a given investment stage.
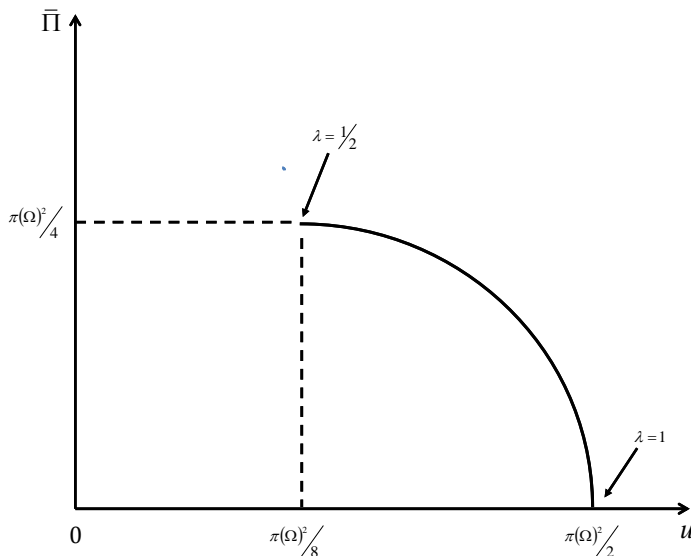
Figure B.5: Bargaining frontier. On the vertical axis is the profit of the VC and on the horizontal axis the utility of the EN.

Substitute λ into the profit function of the VC firm to obtain the stage s bargaining frontier

$$\overline{\Pi}(u, \Omega) = q(\tau)(\sqrt{2u}\pi(\Omega(\mu, x(j(\tau)))) - 2u), \tag{B.10}$$

where $u \in [\pi(\Omega)^2/8, \pi(\Omega)^2/2]$. Note that the bargaining (Pareto) frontier is decreasing for all the permissible values of u. Moreover, the equity is $\lambda = 1/2$ when $u = \pi^2/8$ (lowest entrepreneur utility) and it increases as u increases (see Figure B.5). Note that the slope of the Pareto frontier ranges from zero (when $\lambda = 1/2$) to minus one (when $\lambda = 1$). A higher stage specialization τ affects the profits of VC firm j through two channels, *holding* u fixed: first, the firm will fund more stage s projects, higher q, and second the profit from each project it funds increases, higher x, because the expertise of the VC increases. However, once we embed the isolated VC-EN pair into the market there will be a third, competitive, effect coming through entrepreneurs' outside option u.

B.1.2 Properties of the Matching Equilibrium

Now we embed the VC-EN pair into the market and we endogenize entrepreneurs' outside option u. Our goal, after we derive the equilibrium u, is to examine how the competitiveness of the VC market will affect u which in turn affects VC profits and the incentives to choose stage

specialization. We define the equilibrium of the VC market when each VC firm matches with one entrepreneur in stage s (one-to-one matching).[56]

Definition 1 (Matching Equilibrium) *An equilibrium of the VC market in stage s consists of $\tau_1^*(j)$, $\tau_2^*(j)$ and a one-to-one matching function $m : E \to V$ and payoff allocations $\Pi^* : V \to \mathbb{R}_+$ and $u^* : E \to \mathbb{R}_+$, that satisfy the following conditions:*

(i) *Each VC firm j maximizes its payoff function through its stage specialization choices τ_1^* and τ_2^*. The specialization choices along with the initial VC distribution generate an ex-post VC distribution of VC expertise in each stage.*

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

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

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

Hong, Serfes and Thiele (2013) have proved that the equilibrium matching is positive assortative (PAM), by demonstrating that the two sufficient conditions for a PAM in Legros and Newman (2007) are satisfied. This result also holds for our model. Positive assortative matching (PAM) implies that the matching function $m(i)$ is increasing in i. Note that the measure of entrepreneurs 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 $m(i)$:

$$\frac{dm(i)}{di} = G^{-1\prime}(H(i)) = \frac{h(i)}{G'(G^{-1}(H(i)))} = \frac{h(i)}{g(m(i))}. \tag{B.11}$$

The slope of the matching function $m(i)$ is equal to the ratio of the densities of entrepreneur and VC types, $h(i)$ and $g(m(i))$. Given the last entrepreneur $\underline{i}$, there will be a cutoff expertise level below which VC firms do not enter the market. The lowest-quality VC in the market is

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

thus defined by $m(\underline{i}) = \underline{j}$. We henceforth use the index i when referring to the match between entrepreneur i and VC firm $m(i)$.

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

Lemma 1 *The equilibrium outside option $u^*(i)$ for entrepreneur i in stage s, with $i > \underline{i}$, is characterized by the ordinary differential equation*

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

with the initial condition $u^*(\underline{i}) \equiv \pi(\underline{i})^2/8$.

According to the Picard-Lindelöf Theorem (e.g. Birkhoff and Rota (1989)), a unique solution $u^*(i)$ to (B.12) exists.[57] The unique solution $u^*(i)$ must then (implicitly) satisfy

$$u^*(i|\underline{i}) = \frac{\pi(\underline{i})^2}{8} + \int_{\underline{i}}^{i}\frac{du^*(s)}{ds}ds. \tag{B.13}$$

We would like to examine the effect of competition on the equilibrium utility of entrepreneurs, $u^*(i)$. The VC market in stage s becomes more competitive if more entrepreneurs and VCs enter the market, i.e., $\underline{i}$ decreases. As we have already noted in the main text, this is also consistent

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[57]We need $du^*(i)/di$ to be Lipschitz continuous in u and continuous in i. Our assumptions ensure that $du^*(i)/di$ is continuous in i, because i enters $du^*(i)/di$ through $\mu(i)$. The term u enters $du^*(i)/di$ (i) linearly in the numerator and (ii) in a square root in the denominator. If a differentiable function has a derivative that is bounded everywhere by a real number, then the function is Lipschitz continuous. The linear term and the square root term in $du^*(i)/di$ are both Lipschitz continuous, because u is bounded away from zero. In Section B.2, we offer a specific example where we calculate the unique solution $u^*(i)$.

with empirical evidence where entry in a market is predominantly from VC firms with experience much lower than that of the incumbents. Differentiating (B.12) with respect to $\underline{i}$ we obtain

$$
\begin{aligned}
\frac{d}{d\underline{i}}\left(\frac{du^*(s)}{ds}\right) &= \frac{2\frac{du^*}{d\underline{i}}\frac{\partial \pi(\Omega)}{\partial \Omega}\frac{\partial \Omega}{\partial \mu}\frac{d\mu(i)}{di}\left(\sqrt{2u^*}-\pi\right)}{\left(2\sqrt{2u^*}-\pi\right)^2} = \frac{2\frac{du^*}{d\underline{i}}\frac{\partial \pi(\Omega)}{\partial \Omega}\frac{\partial \Omega}{\partial \mu}\frac{d\mu(i)}{di}\left(\lambda\pi-\pi\right)}{\left(2\lambda\pi-\pi\right)^2} \\
&= \frac{2\frac{du^*}{d\underline{i}}\frac{\partial \pi(\Omega)}{\partial \Omega}\frac{\partial \Omega}{\partial \mu}\frac{d\mu(i)}{di}\left(\lambda-1\right)}{\pi\left(2\lambda-1\right)^2} > 0.
\end{aligned} \tag{B.14}
$$

Hong, Serfes and Thiele (2013) have proved that $du^*/d\underline{i} < 0$ (the equilibrium utility $u^*(i)$ increases with entry). Given this, and since $\lambda < 1$, the above expression is positive. This suggests that as the market becomes more competitive $u^*(i)$ increases but the slope of $u^*(i)$ decreases (we offer an intuition in Section 2).

Next, we examine how the above change depends on i. In other words, as we move up the ladder, does the decrease in the slope of $u^*(i)$ due to more competition become more or less pronounced? We differentiate (B.14) with respect to i. Moving up the ladder, i.e., increasing i, affects (B.14) in four ways: i) $du^*(i)/d\underline{i}$ changes, ii) λ changes, iii) the slope of $\mu(i)$ changes and iv) a higher i means a higher $x(j)$ through matching and a higher x affects Ω. Below we present the outcome of differentiation without the denominator which is positive.

$$
\begin{aligned}
\frac{d}{di}\left\{\frac{d}{d\underline{i}}\left(\frac{du^*(i)}{di}\right)\right\} &= \Big(2\frac{\partial^2 u^*}{\partial \underline{i}\partial i}\frac{\partial \pi(\Omega)}{\partial \Omega}\frac{\partial \Omega}{\partial \mu}\frac{d\mu}{di}(\lambda-1) + 2\frac{du^*}{d\underline{i}}\frac{\partial \pi(\Omega)}{\partial \Omega}\frac{\partial \Omega}{\partial \mu}\frac{d\mu(i)}{di}\frac{d\lambda}{di} \\
&+ 2\frac{du^*}{d\underline{i}}\frac{\partial \pi(\Omega)}{\partial \Omega}\frac{\partial \Omega}{\partial \mu}\frac{d^2\mu}{di^2}(\lambda-1) + 2\frac{du^*}{d\underline{i}}\frac{\partial \pi(\Omega)}{\partial \Omega}\frac{\partial^2 \Omega}{\partial \mu\partial x}\frac{dx(j)}{di}\frac{d\mu(i)}{di}(\lambda-1)\Big)\pi(2\lambda-1)^2 \\
&- \left(2\frac{du^*}{d\underline{i}}\frac{\partial \pi(\Omega)}{\partial \Omega}\frac{\partial \Omega}{\partial \mu}\frac{d\mu}{di}(\lambda-1)\right)\left(\frac{d\pi}{di}(2\lambda-1)^2 + 4\pi(2\lambda-1)\frac{d\lambda}{di}\right).
\end{aligned}
$$

All terms are negative except the term with the cross partial derivative of Ω with respect to μ and x. This term measures the complementarity of the skills of the VCs and entrepreneurs. A higher expertise VC benefits more from a higher quality entrepreneur than a lower expertise VC. Therefore, a higher expertise VC is willing to pay more for a higher quality entrepreneur and that is why the sign of that term is opposite from the signs of all the other terms.

As long as the complementarity term is not very strong, the above derivative is negative suggesting that the decrease in the slope of u^* when the market becomes more competitive is less pronounced when i is higher. The numerical example of the next Section confirms this result. The following proposition summarizes.

Proposition 1 *As the VC market becomes more competitive i.e., $\underline{i}$ decreases, the equilibrium utility $u^*(i)$ of entrepreneurs increases for all i. Moreover, $du^*(i)/di$ decreases and this decrease, provided that $\partial^2\Omega/(\partial\mu\partial x)$ is not very strong, is less pronounced for higher i.*
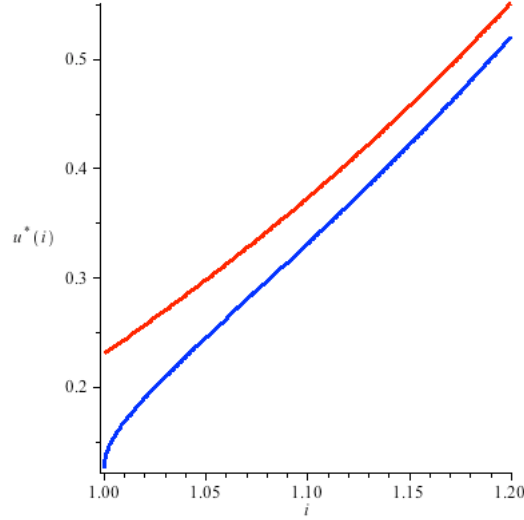
Figure B.6: Based on the numerical example in Section B.2. The higher curve represents the equilibrium entrepreneurial utilities, $u^*(i)$, from a more competitive market than the lower curve. Competition increases the utility of entrepreneurs and this increase is higher at the lower end of the market. It also decreases the slope of $u^*(i)$, with the bigger effect taking place at the low end of the curve.

A corollary from the proposition above is that $u^*(i)$ increases more for lower i's. As we move higher up the ladder the effect of competition on $u^*(i)$ subsides, as Figure B.6 shows.

B.2   A Numerical Example

We assume that i and j are distributed in $[1, 1.2]$ with the same distribution functions. This implies that the matching function has slope equal to one, that is $i = j$ in equilibrium. Moreover, $\pi(\Omega) = ij$. When the market becomes more competitive i and j are distributed in $[0.9, 1.2]$. We focus on one stage of investment and, for simplicity, we assume that whatever happens in one stage is replicated in the other. Each VC firm, however, is positioned on different points on the matching curve in each stage due to the (possibly) different stage specialization decisions it has made.

We solve the ODE (B.12) numerically using the Maple software. Figure B.6 depicts two $u^*(i)$'s. The higher curve is the $u^*(i)$ associated with the more competitive VC market. To illustrate our main point let's focus on two i's: $i = 1.05$ and $i = 1.2$. These are two different entrepreneurs, the one with the higher i has a better project. Let's use H and L to denote a more and a less competitive market respectively. Then $u_H^*(1.2) = .5511$, $u_L^*(1.2) = .5201$, $u_H^*(1.05) = .2972$, $u_L^*(1.05) = .2442$. As it can be seen, the impact of competition is more pronounced for $i = 1.05$ (low end of the market). The utility of $i = 1.05$ increases more when

competition intensifies than the utility of $i = 1.2$. In some sense, higher quality VC-EN pairs are more insulated from the competitive forces than the low quality VC-EN pairs. Now let's turn to the slopes of u^* with respect to i: $(u_H^*)'(1.2) = 2.0048$, $(u_L^*)'(1.2) = 2.081$, $(u_H^*)'(1.05) = 1.4201$, $(u_L^*)'(1.05) = 1.7365$. These slopes measure how much more utility a VC firm has to give to an entrepreneur with a higher i. The $u^*(i)$ for the more competitive market is flatter and moreover the change in the slopes is more pronounced at the low end of the market.

B.3   VC Firm Chooses Stage Specialization

If a VC firm increases its stage s specialization τ_s its ranking j will also increase according to $j(\tau_s)$. From the matching function $j = m(i)$, i will also increase according to $m^{-1}(j)$, which in turn will increase $u^*(i)$. What we just described is the competitive effect of specialization. Therefore, the bargaining frontier, (B.10), can be written as $\overline{\overline{\Pi}}(\tau) \equiv q(\tau)(\sqrt{2u(m^{-1}(j(\tau)))}\pi(\Omega(\mu, x(j(\tau)))) - 2u(m^{-1}(j(\tau)))$. The problem the VC firm solves is given by (1), (see Section 2.1).

The effect of τ_s on $\overline{\overline{\Pi}}_s$ can be written as follows

$$\frac{d\overline{\overline{\Pi}}_s}{d\tau_s} = \left(\underbrace{\frac{\partial \overline{\overline{\Pi}}}{\partial u}\frac{du^*}{di}\frac{di}{dj_s}}_{(-)} + \underbrace{\frac{\partial \overline{\overline{\Pi}}}{\partial \Omega}\left(\frac{\partial \Omega}{\partial x_s}\frac{dx_s}{dj_s} + \frac{\partial \Omega}{\partial \mu}\frac{d\mu}{di}\frac{di}{dj_s} \right)}_{(+)} \right) \frac{dj}{d\tau_s}. \tag{B.15}$$

The above expression demonstrates the effect of the slope of $u^*(i)$, $du^*(i)/di$, on the marginal profitability of stage s specialization. As we have already argued, the slope of $u^*(i)$ captures the cost of a marginally higher stage s specialization for the VC firm. When this slope increases (all else equal), the marginal profitability for the VC firm decreases.

Let's assume that VC firm $j = m(i)$ has chosen τ_1^* and τ_2^*, with $\tau_1^* \geq \tau_2^*$. Thus, firm j is more specialized in stage 1, implying that its ranking is higher in stage 1 than in stage 2. It also implies that the VC firm funds more stage 1 than stage 2 projects. Suppose now the market becomes more competitive, that is $\underline{i}$ decreases. There will be two *opposing* effects. The strength of these two effects follows from Proposition 1. First, $\overline{\overline{\Pi}}_2$ decreases more than $\overline{\overline{\Pi}}_1$, due to the fact that the increase of $u^*(i)$ is higher for lower i's (see also the numerical example of Section B.2, where u^* increases more for $i = 1.05$ than for $i = 1.2$). Specialization increases, i.e., τ_1^*/τ_2^* increases.

Second, $d\overline{\overline{\Pi}}_1/d\tau_1$ and $d\overline{\overline{\Pi}}_2/d\tau_2$ increase, because $du^*(i)/di$ decreases (see (B.15)). Furthermore, $d\overline{\overline{\Pi}}_2/d\tau_2$ increases more than $d\overline{\overline{\Pi}}_1/d\tau_1$ (in the numerical example of Section B.2 the slope of u^* decreases more for $i = 1.05$ than for $i = 1.2$). The firm will specialize less, i.e., τ_1^*/τ_2^* decreases.

Overall, the net effect of market competition on VC firm specialization depends on the strength of the two opposing effects.

References

[1] Aghion, Philippe, Nick Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt. "Competition and Innovation: An Inverted-U Relationship," *Quarterly Journal of Economics* 120 (2), 701-728 (2005).

[2] Barry, Christopher B. "New Directions in Research on Venture Capital Finance." *Financial Management*, 23, 3-15 (1994).

[3] Berger, Phillip, and Eli Ofek. "Diversification Effect on Firm's Value," *Journal of Financial Economics* 37, 3965 (1995).

[4] Birkhoff, Garrett and Gian-Carlo Rota. *Ordinary Differential Equations*, John Wiley and Sons Inc. (1989).

[5] Campbell, Katharine. "Smarter Ventures: A Survivor's Guide to Venture Capital Through the New Cycle," Prentice Hall (2003).

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

[7] Da Rin, Marco, Thomas Hellmann and Manju Puri. "A Survey of Venture Capital Research," in the Handbook of the Economics of Finance, Chapter 8 (2013).

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

[9] Fulghieri, Paolo and Merih Sevilir. "Size and Focus of a Venture Capitalist's Portfolio," *Review of Financial Studies*, v22, n11, 4643-4680 (2009).

[10] Garicano, Luis and Thomas N. Hubbard. "Managerial Leverage Is Limited by the Extent of the Market: Hierarchies, Specialization, and the Utilization of Lawyers' Human Capital," *Journal of Law and Economics*, vol. 50, 1-43 (2007).

[11] Garicano, Luis and Thomas N. Hubbard. "Specialization, Firms, and Markets: The Division of Labor within and between Law Firms," *Journal of Law, Economics and Organization*, vol. 25, 339-371 (2009).

[12] Gompers, Paul, Anna Kovner and Josh Lerner. "Specialization and Success: Evidence from Venture Capital," *Journal of Economics & Management Strategy*, v18, n3, 817-844 (2009).

[13] Gompers, Paul, Anna Kovner, Josh Lerner and David Scharfstein. "Venture Capital Investment Cycles: The Impact of Public Markets," *Journal of Financial Economics*, v87, 1-23 (2008).

[14] Gompers, Paul and Josh Lerner. "An Analysis of Compensation in the U.S. Venture Capital Partnership," *Journal of Financial Economics,* 51, 3-44 (1999).

[15] Gompers, Paul, and Josh Lerner. "Money Chasing Deals?: The Impact of Fund Inflows on the Valuation of Private Equity Investments," *Journal of Financial Economics,* 55, 281-325 (2000).

[16] Grossman, Gene M., and Carl Shapiro. "A Theory of Factor Mobility," *Journal of Political Economy* 90:1054-69 (1982).

[17] Hashmi, Aamir R. "Competition and Innovation: The Inverted-U Relationship Revisited," *Review of Economics and Statistics,* v95, n5, 1653-1668 (2013).

[18] Han, Xi. "The Specialization Choices and Performance of Venture Capital Funds," working paper (2009).

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

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

[21] Hong, Suting, Konstantinos Serfes and Veikko Thiele. "The Market for Venture Capital: Entry, Competition and the Survival of New Companies," working paper (2013).

[22] Hong, Suting. "Competition, Syndication and Entry in the Venture Capital Market," working paper (2013).

[23] Hsu, David. "What Do Entrepreneurs Pay For Venture Capital Affiliation?" *Journal of Finance,* 59, 1805-1844 (2004).

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

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

[26] Inderst, Roman, Holger M. Mueller and Felix Muennich. "Financing a Portfolio of Projects," *Review of Financial Studies,* 20, 1289-1325 (2007).

[27] Kaplan, Steven N., Berk A. Sensoy and Per Strömberg. "How well do Venture Capital Databases Reflect Actual Investments?" Working Paper, (2002).

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

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

[30] Kim, Sunwoong. "Labor Specialization and the Extent of the Market," *Journal of Political Economy* 97:692-705 (1989).

[31] Kortum, Samuel and Josh Lerner. "Does Venture Capital Spur Innovation?" *Rand Journal of Economics,* 31, 674-692, (2000).

[32] Lang, Larry H. P., and Rene M. Stulz. "Tobin's q, Diversification and Firm Performance," *Journal of Political Economy* 102, 12481280 (1994).

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

[34] Lerner, Josh. "Venture Capitalists and the Oversight of Private Firms," *Journal of Finance,* 50, no. 1, 301-318, (1995).

[35] Murphy, Kevin M. "Specialization and Human Capital," Unpublished Ph.D. dissertation. University of Chicago, Chicago (1986).

[36] National Venture Capital Association. "Venture Impact: The Economic Importance of Venture Backed Companies to the U.S. Economy," (2011).

[37] Sahlman, William A. "The Structure and Governance of Venture-capital Organizations." *Journal of Financial Economics*, 27, 473-521 (1990).

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

[39] Santalo, Juan and Manuel Becerra. "Competition from Specialized Firms and the Diversification–Performance Linkage," *Journal of Finance* VOL. LXIII, NO. 2, 851-883 (2008).

[40] Sattinger, Michael. "Assignment Models of the Distribution of Earnings." *Journal of Economic Literature*, 31(2): 831-880 (1993).

[41] Smith, Adam. "An Inquiry into the Nature and Causes of the Wealth of Nations," (1776).

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

[43] Sorenson, Olav and Toby E. Stuart. "Syndication Networks and the Spatial Distribution of Venture Capital Investment," *The American Journal of Sociology,* 106(6), 1546-1588 (2001).

[44] Stigler, George. "The Division of Labor is Limited by the Extent of the Market," *Journal of Political Economy* 59, 185193 (1951).

[45] Terviö, Marko. "The Difference That CEOs Make: An Assignment Model Approach," *American Economic Review,* 98:3, 642-668 (2008).

[46] Teulings, Coen N. "The Wage Distribution in a Model of the Assignment of Skills to Jobs." *Journal of Political Economy*, 103(2): 280-315 (1995).

[47] Uetake, Kosuke. "Strategic Network Formation and Performance in the Venture Capital Industry," unpublished manuscript (2012).

[48] van Lamoen, Ryan C.R., Jaap W.B. Bos and Claire Economidou. "Too Big to Innovate? Scale (dis)economies and the Competition-Innovation Relationship in U.S. Banking,"unpublished manuscript (2010).