JOURNAL OF FINANCIAL AND QUANTITATIVE ANALYSIS Vol. 59, No. 3, May 2024, pp. 1362–1400

doi:10.1017/S0022109023000297

Informational Holdup by Venture Capital Syndicates

Suting Hong
ShanghaiTech University School of Entrepreneurship and Management
hongst@shanghaitech.edu.cn

Pierre Mella-Barral
TBS Business School
p.mella-barral@tbs-education.fr (corresponding author)

Abstract

We argue that syndicates associate venture capitalists (VCs) with uneven skill levels in order to lower their expected gains from threatening to stop financing: Non-continued participation would send a milder negative signal to alternative financiers. This can explain the empirical observations that i) early-round syndicates regularly associate VCs with different levels of experience and ii) follow-on syndicates often involve none of the early-round VCs. Consistent with the theory, we find empirically that the heterogeneity of VC experience levels in a syndicate is i) negatively related to the extent to which the founders of the VC-backed firm are professionally well connected and ii) positively related to the likelihood of syndicate switching in a later round.

I. Introduction

We develop a theory of informational holdup by incumbent VC syndicates in staged investment projects. An entrepreneur seeks VC financing for her project. The project quality is uncertain, but the required investment can be staged. An early investment delivers information about the quality of the project before the follow-on investment is needed. VCs are financiers with an ability to interpret information and obtain a signal about the quality of the project. The VCs who finance the early round obtain an informational advantage over alternative VCs. There exist VCs with different skill levels, with more skilled VCs obtaining more accurate signals. VCs invest as part of a syndicate of N VCs, because the follow-on investment is only worthwhile if N positive signals are received. The question we address is: Which VC syndicate is most attractive to the entrepreneur in the early round?

The entrepreneur prefers an early-round syndicate whose aggregate skill level is *intermediate.* The higher the skill levels of the VCs, the more they will value the project accurately and the more attractive early-round offer the syndicate can make.

We acknowledge very helpful insights from an anonymous referee, Xiangwei Wan (discussant), Chengsi Wang, and seminar participants at Monash University, Nanjing University, East China Normal University, TBS, and ShanghaiTech University. We also thank Xingsheng Yang and Yixuan Zhao for excellent research assistance. Suting Hong acknowledges supports from the ShanghaiTech University Start-Up Fund. Any errors are entirely our own.

However, if the incumbent syndicate does not finance the follow-on round, alternative syndicates update their beliefs taking into account this negative signal of nonparticipation. A syndicate consisting of most skilled VCs is unattractive because it can extract the full value of the project in the follow-on round: If it does not finance the follow-on round, it becomes impossible for the entrepreneur to find alternative financing. The lower the skill levels of the VCs in the early-round syndicate, the higher the reservation value of the entrepreneur in the follow-on round, and the less the incumbent syndicate can capture value.

Among syndicates with the optimal intermediate aggregate skill level, the syndicate that is most attractive to the entrepreneur consists of VCs with most *heterogeneous* levels of skills. Disparity in VC skill levels renders the negative signal of nonparticipation of the incumbent syndicate milder: Conditional on the incumbent VCs not all receiving a high signal, it i) enhances the probability that they received opposite signals and ii) lowers the probability that they all received negative signals. Intuitively, disparity in VC skill levels makes that, in the event that the incumbent syndicate does not finance the follow-on round, it is more likely to be because one less skilled VC which makes more mistakes received a bad signal, different from the signal received by others.

This makes that alternative VCs are more comfortable to fund the firm. Heterogeneity in VC skill levels reduces the negative impact of the signal of nonparticipation of the incumbent syndicate on the updated beliefs of an alternative syndicate. This weakens the potential for holdup by the incumbent syndicate in the follow-on round because it increases the likelihood the entrepreneur can find alternative financing.

The argument applies for any type of heterogeneity. VCs join forces in syndicates to access N signals. This may be because the project involves N technically distinct dimensions and it is beneficial to have the opinions of N complementary specialist VCs who each have a different type of expertise. Or, the project is not technically multidimensional and it is beneficial to have N opinions of substitutable generalist VCs, instead of just one opinion. In the former, each VC assesses one separate part of the project. In the latter, the entire project is assessed by each VC. Our argument is transversal to the VCs having skill types that are complements or substitutes. It is about heterogeneity in their skill levels.[1]

The equilibrium outcome has therefore the following features:

(a) Entrepreneurs prefer an early-round syndicate of VCs with different skill levels.
(b) Syndicate switching occurs: The project has a chance of finding follow-on financing, even if the incumbent syndicate refused to participate.

We analyze the impact of the informational advantage of incumbent VCs over alternative VCs on the equilibrium outcome. We show that when alternative VCs are at a larger disadvantage, the entrepreneur prefers an early-round syndicate

[1]In the model, we take the number of VCs in a syndicate to be equal to the number of positive signals a syndicate requires to find the follow-on investment worthwhile. We do not provide a theory of the optimal number of VCs in syndicates. As the focus of our study is on the entrepreneur-versus-VC-syndicate conflict of interest, we do not model VC coordination problems, conflicts of interest within syndicates, or private costs incurred to obtain signals.

where the VCs have more unequal skill levels. Because the early-round syndicate has less influence on alternative VCs, syndicate switching in the follow-on round occurs more often. The theory yields the following predictions:

(i) The heterogeneity of VC skill levels in the early-round syndicate is increasing in the informational disadvantage of alternative VCs.
(ii) The probability of syndicate switching in the follow-on round is increasing in the heterogeneity of VC skill levels in the early-round syndicate.

These results are developed in a model with two rounds of investments. How do they apply when the project has more than two rounds of investment? For any number of rounds, all of our results directly transpose to the penultimate round and the last round. Then backward in round number, VC syndicates who invest in rounds prior to the penultimate round have increasingly more options to hold up the entrepreneur than considered by our model: They have a compound option to successively hold up the entrepreneur in each of the remaining rounds.[2] This backward compounding effect suggests that our results (a), (b), (i), and (ii) should be stronger in early financing rounds than in the penultimate round.

This theory is in the spirit of the banking theories of Sharpe (1990) and Rajan (1992). The key informational asymmetry postulated here is that the early-round VC syndicate obtains information about the project which the entrepreneur cannot credibly communicate to others. The resulting informational advantage over alternative VC syndicates gives the incumbent syndicate ex post monopoly power vis-a-vis the entrepreneur in the follow-on round of investment. In the above banking theories of informational holdup by the financing bank, a firm is "informationally captured" as it stays with the same bank although that bank does not make the best offer (Sharpe (1990)) and the bank extracts value from the firm in exchange of continued financing (Rajan (1992)). In Azarmsa and Cong (2020), the entrepreneur controls the information production. This reduces the lender's ex post monopoly power, but impedes relationship finance itself, as the entrepreneur now inefficiently holds up the financier. Several papers study informational holdup by the financier in the context of venture capital. In Fluck, Garrison, and Myers (2009), a commitment to later-round syndication restrains the temptation of the early-round VC to hold up the entrepreneur. In Mella-Barral (2020), the more experienced the incumbent VC is, the stronger the negative signal sent by his nonparticipation to alternative financiers would be. Then the more he can extract ex post concessions from the entrepreneur.

It is a common feature of venture capital financing that investments are staged. Investment in a project is staged when capital is infused over time in a sequence of financing rounds. Staging gives abandonment options. It allows a VC to observe

[2]For projects with M rounds of investment, investors in the penultimate round $M-1$ have exactly the same simple option to hold up the entrepreneur in the last round M as in our 2-round model because financing the last round does not open any option later. Investors in the ante-penultimate round $M-2$ have a compound option of order 1 to hold up in the penultimate round $M-1$, in that this option to hold up contains an embedded simple option to hold up in the last round M. Working backward, investors in round $M-J$ have a compound option of order $J-1$ to successively hold up the entrepreneur in the J remaining rounds.

interim information about a project's viability before continuing financing (Gompers (1995)). The ability to deny financing mitigates the risk the VC faces of being held-up by the entrepreneur, as it pushes the entrepreneur to exert effort, not to divert cash flows and not to manipulate short term appearances (Bergemann and Hege (1998), Noldeke and Schmidt (1998), Neher (1999), Landier (2002), Cornelli and Yosha (2003), and Yung (2019)). VCs emphasize their ability to interpret information so as to assess projects accurately. The level of this ability is primarily determined by past experience, with more experienced VCs better at screening and selecting entrepreneurial projects (Lerner (1994)).[3]

A second common feature of venture capital financing is that VCs form syndicates. Two or more VCs form a syndicate when they jointly finance an investment round. Syndication has reinforcing effects. It improves accuracy, as more than one VC evaluates the project before an additional round of investment is financed.[4] Incentive problems arise between associates, but syndication is a coordination device that prevents profit-dissipating competition between VCs from actually taking place (Casamatta and Haritchabalet (2007)). Syndicating VCs can be induced to truthfully reveal their non-verifiable and manipulable signals to each other with an appropriate design of cash-flow rights (Cestone, Lerner, and White (2008)). A common feature of these agency theories is that higher accuracy is always desirable. Other things being equal, entrepreneurs prefer being financially backed by a syndicate of VCs with highest skill levels.

We take the theory to the data using a novel data set from PitchBook that includes all the VC investments in the United States between 2010 and 2014. The data provide detailed information not only on VC investment rounds and VC-backed ventures, but also on individuals' professional and educational experience of founding team members affiliated with those VC-backed ventures. We look at all U.S. VC funding rounds that involved at least 1 conventional VC firm in the 5-year window between 2010 and 2014. We use past experience as a proxy for VC skill level by simply counting the number of investment rounds the VC firm has participated to date since 1975. We observe:

(a) Within VC syndicates, VCs have regularly different levels of experience: Across all investment rounds, the experience of the VCs which compose a syndicate have at mean level a coefficient of variation equal to 0.74 and a GINI coefficient equal to 0.66. If VCs associated randomly, these values would be much lower.[5]

[3]Past experience is one of the strongest sources of differentiation among VCs: Entrepreneurs are willing to forego offers with higher valuations in order to affiliate with more experienced VCs (Hsu (2004)) and there exists a positive sorting mechanism in which more experienced VCs invest in better projects (Sørensen (2007)).

[4]Syndication also permits VCs to diversify their portfolios. Venture capital returns are skewed: VCs write off over half of their investments and generate a substantial portion of their return from just a few highly successful ventures (Kerr, Nanda, and Rhodes-Kropf (2014)). Syndication allows VCs to share risks so as to increase the odds of having a huge success.

[5]Both normalized measures can take values between 0 (all equal) and 1 (most dispersed). Simulations indicate that if VCs had experience levels which were uniformly distributed and formed syndicates randomly, these mean level values would be between 0.20 and 0.41 (depending on syndicate size). See Section III.B and Table 1.

(b) From one round of investment to another, complete switching of VCs is more common than one might expect: As much as 19% of syndicated rounds have *all* of the investing VCs no longer investing in any of the subsequent rounds, conditional on an entrepreneur receiving subsequent funding.

These features are somewhat more pronounced in early rounds of investments. Table 2 gives a complete by-round comparison. It appears that heterogeneity of VC experience levels and switching rate decline with round sequence numbers.

We are not the first to notice this sort of anomalies: Lerner (1994) finds evidence that within the top two quintiles of VC firms, first-round syndicates have disproportionately heterogeneous levels of experience.[6] Cumming and Dai (2013) report that 23% of follow-on rounds of financing have lead VCs (defined as the VC that had invested the largest cumulative amount of capital by the time of the round of interest) that are different from those of the previous rounds.

There can be other reasons for the empirical observations (a) and (b). A first explanation is based on a friends and family effect. Conventional wisdom suggests that entrepreneurial firms go to friends or family before resorting to outside sources for funding support. Entrepreneurs will likely secure funds from institutions at which their friends and family have connections. Well-connected and experienced entrepreneurs are connected to other reputable experienced people. This means that if an entrepreneur obtains funding through friends or family, their VC investors are likely to be similar in experience and thus present low heterogeneity within a syndicate. This implies that syndicate heterogeneity is negatively correlated to the extent to which the entrepreneur sought funding from friends or family. Furthermore, an entrepreneur is more likely to stick with investors with whom they build connections through friends or family, leading to a positive relationship between syndicate heterogeneity and switching of investors in later rounds.

A second explanation comes from differences in outside opportunities. The time of a more experienced VC with substantial outside opportunities may be more valuable than that of a less experienced VC. The more experienced VC will collaborate with the less experienced VC and rely on him/her for groundwork and due diligence. The less experienced VC will do most of the work for a smaller cut and will be easy to control because he/she benefits from learning by doing. Syndicate switching will then occur as the opportunity costs of the different VCs change over time.[7] A third explanation comes from differences in areas of expertise. To assess projects which are technically multidimensional, it is clearly helpful to form syndicates of VCs with different areas of expertise. If VCs with different areas of expertise had a tendency to have systematically different levels of experience,

[6]Although Lerner's study is largely seen as providing evidence that established VCs (measured by size) syndicate with other established partners, he noticed some inconsistent patterns in the data and remarked that: *"It is not obvious, for instance, why top-tier firms syndicate first round investments more frequently with second-quintile organizations (35%) than with other top-quintile firms (14%)."* Second-tier firms also choose to syndicate first-round investments more frequently with top-quintile partner (27%) than with other second-quintile firms (25%).

[7]Ewens et al. (2016) find that projects where only previous VCs participate to follow-on financings are 20% more likely to lead to failures than projects where new VCs participate. They attribute this to changing opportunity costs of VCs over the VC fund's life cycle.

then we would observe that more experienced VCs will syndicate with less experienced VCs.[8]

In light of the alternative explanations, we use the following strategy in empirical analysis. First, in building the sample, we exclude all observations of rounds that are likely backed by friends or family of founders. Those excluded rounds either present small investment size or involve investors that likely have connections with members on a founding team through mutual educational or professional experience. We also exclude all deals labeled as "Angel (Individual)" or involving undisclosed individual investors or investors that are engaged in few investments.[9] Second, when examining factors that are related to heterogeneity of VC syndicate, we perform robustness tests by including fixed effects of lead VC firms that capture time-invariant component of preferences in picking syndicate partners. Last, in defining switching, we require that *all* participating investors in a focal round no longer invest in *any* future round received by the entrepreneurial firm. Under this definition, even if some investing entities back out due to changes of opportunity costs or changes of expertise in demand over time, switching does not happen as long as at least one investor continues to invest. This definition is in line with our theory: We characterize holdup by VC syndicate which is most powerful when all members on a syndicate abandon a venture.

We then empirically test the more specific predictions (i) and (ii) of the theory. To quantify the extent of informational disadvantage of alternative VCs, we use a proxy for credibility of entrepreneurs to alternative VCs built through social networks. Part of the information generated by early investments in entrepreneurial firms is soft and not verifiable, and thus entrepreneurs face problems of credibility when she communicates information. Extant literature contends that entrepreneurs rely on networks of social ties to establish legitimacy with key resource holders such as potential investors (Stuart, Hoang, and Hybels (1999), Uzzi (1999), and Hsu (2007)). Therefore, we construct networks consisting of social ties originated from prior founding and professional experience of founding team members of a new venture. We use the network closeness centrality as a proxy for credibility of entrepreneurs to alternative VCs. In building the network, we consider social ties owned by founding team members through taking a diverse variety of professional roles, including founders, employees, advisors, and board members. The networks reflect the social ties owned by entrepreneurial firms up to the time of a funding round, and update by years to capture any newly formed links and turnovers of founding teams.

Our empirical results are consistent with the theoretical predictions:

(i) We find that the heterogeneity in experience levels of VC syndicate partners is negatively related to network centrality score of an entrepreneurial firm. This negative relationship is statistically significant for the first and second rounds of funding. The results are robust to including lead VC firm fixed effects to control for time-invariant preferences of lead VC firms in picking their

[8]Hochberg, Lindsey, and Westerfield (2015) analyze the extent to which VCs syndicate in order to aggregate four orthogonal resources (experience itself, available capital, investment scope, and access) and find little evidence of similarity-based matching.

[9]We provide a detailed description of the sample in Section III.A.

syndicate partners. In light of potential selection bias due to syndicate formation, we perform a 2-step Heckman procedure of estimation and find that our results remain intact.

(ii) Using a sample of syndicated funding rounds that successfully receive subsequent funding after the focal rounds, we track the occurrence of ALL_SWITCH that identifies *all* of the syndicate members no longer invest in any subsequent rounds. We find that higher heterogeneity in experience levels of VC syndicate partners is associated with higher likelihoods of ALL_SWITCH in subsequent funding rounds. This negative relationship is statistically significant for rounds of all sequence numbers. We further control for selection by jointly estimating a system of equations that allow for correlations of error terms in equations describing the following events: syndication, survival, and switching by all syndicating members in follow-on rounds. Our results are robust to controlling for selection bias.

We carry out empirical analysis by rounds of different sequence numbers and find that the negative relationship between syndicate experience heterogeneity and network centrality is not statistically significant for the third or later rounds of funding. This indicates that the holdup by the investor argument is mostly relevant in early rounds of financing. There are two potential explanations as follows: First, compounding effects (as explained in footnote 1) arise in the early rounds. Second, information opacity surrounding an entrepreneurial venture is most serious in early rounds, which is also in line with findings from previous literature that VCs invest smaller amounts in early rounds than in later rounds due to higher informational asymmetries associated with early-round financing (Gompers (1995)).[10]

We also find that the positive relationship between heterogeneity of VC experience levels in syndicates and likelihoods of VC firms' switching in later rounds remains statistically significant for the third or later rounds of funding. This indicates that switching from syndicates with heterogeneous VC experience levels can take place in later rounds, even though holdup threats by VCs are most pronounced in early rounds.

Cumming and Dai (2013) find the existence of a graduation effect, whereby entrepreneurial firms with upwardly revised perceived probability of success are i) more likely to switch lead VCs and ii) to switch to more reputable new lead VCs. We find a similar positive effect from the proxy of perceived quality of an entrepreneurial firm (i.e., estimated likelihood of success of a venture) on VC switching. Through by-round analysis, we actually find that the graduation effect is statistically significant, but only in rounds later than the third round. This suggests that the two results on syndicate switching nicely complement each other: the holdup by the VC syndicate argument being mostly relevant in earlier rounds of financing, and the graduation argument being mostly relevant in later rounds of financing.

The article is organized as follows: Section II introduces the setup of the model, derives the equilibrium outcome, discusses implications, and formulates

[10]In our data set, the mean deal size (amount invested by VCs in a round) is \$4.18 M for the first rounds, \$6.96 M for the second rounds, \$10.89 M for the third rounds, and \$21.82 M for the fourth and later rounds.

testable hypotheses. Section III describes the data and variables employed in the empirical analysis. Section IV carries out the empirical analysis. Section V concludes.

II. The Model

A. Setup

At date 0, an entrepreneur holds a project which requires an investment of 1 to be realized. The entrepreneur has all intellectual property rights on the project, but no money of her own. There exists a perfectly competitive market for venture capital. VCs are deep pocketed financiers with an ability to interpret information. The entrepreneur and all VCs are risk-neutral and discount at a zero interest rate.

The project can be good (G) or bad (B). At date 0, the entrepreneur and all VCs attach a probability $\pi \in (0,1)$ to the project being of the good type. The required investment can be staged in an early investment $\gamma \in (0,1)$ at date 1 and a follow-on investment $1-\gamma$ at date 2. The project gives a return $\rho \in \mathbb{R}_{>1}$ at date 3, but only if i) the investment of 1 is completed by date 2, ii) the project is good, and iii) the entrepreneur exerts an effort after the early-round investment, incurring a private cost $\varepsilon \in \mathbb{R}_{>0}$. The project generates no return otherwise.

Refer to the VCs who finance the early investment and the entrepreneur as insiders. The early investment γ at date 1 allows insiders to collect firsthand information about the project as it appears in real time between dates 1 and 2. Let $\varphi \in (0,1)$ be the transparency of insiders' information at date 2. At date 2, inside VCs use this information to update their beliefs about the project type before deciding to offer to finance the remaining funds $1-\gamma$.

If inside VCs do not offer follow-on financing at date 2, the entrepreneur can seek alternative financing from other VCs, referred to as outside VCs. Outside VCs are, however, at an informational disadvantage: They do not have a direct access to the information generated by the early investment and the entrepreneur faces problems of credibility when she conveys them this information.[11] Consider that outsiders' information at date 2 is of reduced-transparency $\varphi\theta$, where $\theta \in (0,1)$ is an abatement factor which captures (inversely) the extent of the differential information between insiders and outsiders.

VCs differ in the extent of their ability to interpret a set of information. Some generate a more accurate assessment of the project type than others. Refer to the precision of a VC to assess a given set of information as its skill level.[12] Any VC can receive at date 2 a signal of how good the prospects of the project are which can either be positive or negative. The strength of the signal depends on the skill level of the VC and the transparency of the information he has:

[11] In the empirical analysis, we explore social ties owned by founding team members and use network centrality as a proxy for credibility of entrepreneurial firms. The higher this credibility, the more outside VCs consider highly information conveyed by the entrepreneur, and the lower the informational disadvantage of outside VCs.

[12] In the empirical analysis, following Hsu (2004), Sørensen (2007), Nahata (2008), and Cumming and Dai (2013), we use past experience (counting prior investment rounds) as a proxy for skill level of a VC.

- An inside VC i_n with skill level $\alpha_{i_n} \in (0,1]$ can receive a signal $s_{i_n} \in \{\underline{s}_{i_n}, \overline{s}_{i_n}\}$. Being an insider, the transparency of his information is φ. Consider that the conditional probability, $P(\overline{s}_{i_n}|G)$, of i_n receiving signal $\overline{s}_{i_n}$ if the project is good is[13]

$$p_{i_n} \equiv P(\overline{s}_{i_n}|G) = \frac{1+\alpha_{i_n}\varphi}{2}, \quad \text{with } P(\underline{s}_{i_n}|B) = P(\overline{s}_{i_n}|G). \tag{1}$$

- An outside VC k_n with skill level $\alpha_{k_n} \in (0,1]$ can receive a signal $s_{k_n} \in \{\underline{s}_{k_n}, \overline{s}_{k_n}\}$. Given that outsiders' information is of reduced-transparency $\varphi\theta$, consider that the conditional probability, $P(\overline{s}_{k_n}|G)$, of k_n receiving a signal $\overline{s}_{k_n}$ if the project is good is

$$p_{k_n} \equiv (\overline{s}_{k_n}|G) = \frac{1+\alpha_{k_n}\varphi\theta}{2}, \quad \text{with } P(\underline{s}_{k_n}|B) = P(\overline{s}_{k_n}|G). \tag{2}$$

- The entrepreneur does not have the ability to receive any signal.

The project and the information to be obtained at date 1 are such that VCs only invest if they join forces in a syndicate of $N \in \mathbb{N}_{>1}$ VCs. A syndicate containing less than N VCs is unable to revise upward its beliefs sufficiently at date 2 to justify investing at date 1. N is the number of VCs in a syndicate such that each VC signal is pivotal. We capture that having access to the opinion of N VCs is essential to all VCs as follows:

- If the early investment is financed at date 1, denote $\boldsymbol{i} \equiv (i_1, \ldots, i_N)$ the syndicate which finances it. Denote $\boldsymbol{\alpha}_i \equiv (\alpha_{i_1}, \ldots, \alpha_{i_N})$ and $\boldsymbol{s}_i \equiv (s_{i_1}, \ldots, s_{i_N})$, where $s_{i_n} \in \{\overline{s}_{i_n}, \underline{s}_{i_n}\}$ for all $n \in \{1, \ldots, N\}$, the skill levels of the VCs in $\boldsymbol{i}$ and the signals they receive at date 2.

  It is only worthwhile for the inside syndicate $\boldsymbol{i}$ to offer follow-on financing if $\boldsymbol{s}_i$ is the "all-high" signal $\overline{\boldsymbol{s}}_i \equiv (\overline{s}_{i_1}, \ldots, \overline{s}_{i_N})$. Denote $\overline{\boldsymbol{s}}_i$ any non-all-high signal $\boldsymbol{s}_i \precneqq \overline{\boldsymbol{s}}_i$.

- If the inside syndicate $\boldsymbol{i}$ does not offer follow-on investment at date 2 and another syndicate finances it, denote $\boldsymbol{k} \equiv (k_1, \ldots, k_N)$ the one which finances it. Denote $\boldsymbol{\alpha}_k \equiv (\alpha_{k_1}, \ldots, \alpha_{k_N})$ and $\boldsymbol{s}_k \equiv (s_{k_1}, \ldots, s_{k_N})$, where $s_{k_n} \in \{\overline{s}_{k_n}, \underline{s}_{k_n}\}$ for all $n \in \{1, \ldots, N\}$, the skill levels of the VCs in $\boldsymbol{k}$ and the signal they receive at date 2.

  It is only worthwhile for the outside syndicate $\mathbf{k}$ to offer follow-on financing if $\mathbf{s}_k$ is the "all-high" signal $\overline{\mathbf{s}}_k \equiv (\overline{s}_{k_1}, \ldots, \overline{s}_{k_N})$. Denote $\overline{\mathbf{s}}_k$ any non-all-high signal $\boldsymbol{s}_k \precneqq \overline{\boldsymbol{s}}_k$.

All VCs receive conditionally independent signals. VCs update their beliefs about the project return using Bayes' rule. We abstract from conflicts of interests

[13] φ is the extent to which the information permits VCs to revise their beliefs. α_{i_n} is the extent to which VC i_n is capable of interpreting information accurately. A signal could only be perfectly accurate if both the information was perfectly transparent, $\varphi = 1$, and the VC's skill level was the highest possible, $\alpha_{i_n} = 1$. Conversely, a signal would be completely uninformative, $P(\overline{s}_{i_n}|G) = P(\overline{s}_{i_n}|B) = P(\underline{s}_{i_n}|G) = P(\underline{s}_{i_n}|B) = 1/2$, if either the information was absolutely opaque, $\varphi = 0$, or the VC had no skill, $\alpha_{i_n} = 0$.

between VCs within a syndicate. In a syndicate, VCs simply share their signals and decide cooperatively to make a financing offer or not. VCs do not incur private costs to process information and obtain a signal.

We simply consider that the number of VCs in a syndicate is equal to N, the number of positive signals required for follow-on investment to be worthwhile. We abstract from VC coordination problems and do not model the pros and cons of having a number of VCs in a syndicate larger than N.[14]

Information and signals are not verifiable. Entrepreneurial effort is observable but not contractible. In all contracts, all VCs in a syndicate pay equal "price-per-share" with pari passu rights and, hence, have perfectly aligned incentives. However, a syndicate can decide to offer extra early-round funding to the entrepreneur, in an effort to pre-commit against wrongdoing in the follow-on round. To allow for this, we consider a wide range of contracts. Specifically:

- A date-1 contract is characterized by a triple (D_1, I_1, R_1), whereby a syndicate provides funds $D_1 \geq 0$ and $I_1 \geq \gamma$ at date 1, in return for a payment $R_1 \in [0, \rho]$ at date 3, if the project is good. If the entrepreneur accepts the offer, she is contractually committed to the following usage of the funds at date 1: i) D_1 is immediately paid as a dividend to the entrepreneur; ii) γ is invested in the project; iii) the surplus funds $I_1 - \gamma$ are available for investment in the second round; iv) if the early-round syndicate does not offer follow-on financing and the entrepreneur has to seek financing from outsiders, the funds required to complete financing of the project at date 2 become only $1 - I_1$; and v) in case the entrepreneur does not find alternative financing and investment in the project is not completed, the unused funds $I_1 - \gamma$ are returned to the syndicate.
- A date-2 contract is characterized by a singleton R_2, whereby a syndicate provides the remaining required funds, $1 - I_1$, in return for a payment $R_2 \in [0, \rho - R_1]$ at date 3, if the project is good. Offering contracts which include dividends to the entrepreneur and surplus funds serves no purpose at date 2.

The key informational asymmetry postulated here (as in Sharpe (1990) and Rajan (1992)) is that the informational advantage of inside VCs over outside VCs gives the incumbent VC syndicate ex post monopoly power vis-a-vis the entrepreneur at date 2. To analyze the potential extent of the informational holdup, we develop the polar case where the gain in bargaining power of the incumbent VC syndicate is *highest*: We assume that prior to starting to finance the project, a syndicate has no bargaining power relative to the entrepreneur and that at both dates 1 and 2, there is a competitive supply of VCs with skill level α, for all $\alpha \in [0, 1]$.[15]

[14] In the presence of VC coordination problems, an early round syndicate containing very numerous atomistic VCs has weaker ex post bargaining position and thus reduced ability to hold up the entrepreneur. Also, absent the restriction that syndicates cannot comprise more that N VCs, syndicates containing very numerous VCs would yield the first best outcome. Given that VC signals are independent and VCs incur no private costs, collecting signals from a large number of outside VCs permits to determine with certainty the quality of the project.

[15] In practice, VCs are not in competitive supply prior to financing the project for the first time and do have some bargaining power. The extent of the holdup by the incumbent syndicate is, therefore, less than developed in this benchmark model. In Appendix G of the Supplementary Material, we solve the model under the alternative polar-case assumption that the informational advantage *does not* increase the

The sequence of decisions in the extensive form game is detailed in the Appendix. At date 1, the entrepreneur approaches one syndicate $\boldsymbol{i}$ and that syndicate makes a perfectly competitive date-1 contract offer (such that the expected payoff of the syndicate at date 1 is 0) or no offer. At date 2, the incumbent syndicate $\boldsymbol{i}$ makes a Stackelberg leader follow-on financing date-2 contract offer, or does not make an offer. If the entrepreneur rejects $\boldsymbol{i}$'s follow-on offer or $\boldsymbol{i}$ does not make an offer, the entrepreneur can approach one outside syndicate $\boldsymbol{k}$ and that syndicate makes a perfectly competitive date-2 contract offer or no offer.[16] Otherwise, the project is not financed and the game ends.

B. Equilibrium Outcome

The equilibrium concept we consider is perfect Bayesian equilibrium. The model is solved by backward induction. The derivation of the equilibrium strategy and a detailed proof of Proposition 1 can be found in Appendix A of the Supplementary Material. Here, we only state the equilibrium outcome.

We introduce additional notation based on p_{i_n} in (1) and p_{k_n} in (2): Denote $V_{e,1}$ the payoff at date 1 of the entrepreneur:

$$V_{e,1} = \left(\rho - \frac{1-\gamma}{\underline{q}}\right)\pi \underline{p}^N, \tag{3}$$

$$\text{where } \underline{q} \equiv 1/\left[1 + \frac{(1-\pi)}{\pi}\left(\frac{1-\underline{p}}{\underline{p}}\right)^N J\right], \tag{4}$$

$$\underline{p} \equiv {}_{k_n}\Big|_{\alpha_{kn}=1} = \frac{1+\varphi\theta}{2}, \quad J \equiv \frac{1-\prod_{n=1}^{N}(1-p_{i_n})}{1-\prod_{n=1}^{N} p_{i_n}}. \tag{5}$$

We obtain:

Proposition 1. If $V_{e,1} > 0$, the entrepreneur seeks financing from a syndicate $\boldsymbol{i}$ which belongs to the set $\boldsymbol{\mathcal{S}} = \{(i_1,\ldots,i_N) \,|\, V_{\mathbf{i},1} = 0 \text{ for } R_1 = 0\}$. Syndicate $\boldsymbol{i}$ makes a date-1 offer $(D_1, I_1, R_1) = (0, \gamma, 0)$ and the entrepreneur accepts the offer.

If the inside syndicate $\boldsymbol{i}$ receives the all-high signal $\overline{\mathbf{s}}_i$, it also offers to finance the follow-on round. Syndicate $\boldsymbol{i}$ makes a date-2 offer $R_2 = \rho - \left(\rho - \frac{1-\gamma}{\underline{q}}\right)\underline{p}^N$ and the entrepreneur accepts the offer. Otherwise, $\boldsymbol{i}$ does not offer follow-on financing.

In this latter case, the entrepreneur seeks follow-on financing from an outside syndicate $\boldsymbol{k}$ where all VCs have highest skill levels $\boldsymbol{\alpha}_k \equiv (\alpha_{k_1},\ldots,\alpha_{k_N}) = \mathbf{1}_N$.

bargaining power of the incumbent VC syndicate vis-a-vis the entrepreneur in the follow-on round. There is, then, no informational holdup by the incumbent VC syndicate.

[16] We do not consider the winner's curse between outside syndicates. With multiple bidders, a bidding syndicate would adjust its expectation to reflect that, if its offer is selected, it can infer that the signals received by other bidding syndicates were lower than the ones it received. In the context of Sharpe (1990), see von Thadden (2004).

If the outside syndicate $\boldsymbol{k}$ receives the all-high signal $\overline{\boldsymbol{s}}_k$, it offers to finance the follow-on round and the entrepreneur accepts the offer. Otherwise, the project is not completed.

If $V_{e,1} \leq 0$, the project cannot find financing.

Proposition 1 is best understood starting from the end. Suppose that the early-round syndicate $\boldsymbol{i}$ did not make a follow-on financing offer at date 2 or the entrepreneur rejects $\boldsymbol{i}$'s offer. The entrepreneur seeks follow-on financing from an outside syndicate $\boldsymbol{k}$; otherwise the project generates no return. Proposition 1 states that the most attractive syndicate $\boldsymbol{k}$ only comprises VCs with highest skill levels ($\boldsymbol{\alpha}_k = \mathbf{1}_N$). This is straightforward: i) The game is one shot at this point, ii) an outside syndicate makes a competitive offer, and iii) any outside VC has information of reduced-transparency $\theta\varphi$; then the entrepreneur's expected continuation payoff monotonically increases in the precision of each VC in the outside syndicate.

The outside syndicate $\boldsymbol{k}$ only offers follow-on financing if it receives an all-high signal $\overline{\boldsymbol{s}}_k$. However, when valuing the project, $\boldsymbol{k}$ does not update its beliefs only considering its signal. $\boldsymbol{k}$ also considers that the incumbent $\boldsymbol{i}$ does not finance the follow-on round. Let $\boldsymbol{i}$ denote the signal of non-continued participation of the inside syndicate $\boldsymbol{i}$. In the equilibrium outcome, the updated belief at date 2 of the outside syndicate $\boldsymbol{k}$ (such that $\boldsymbol{\alpha}_k = \mathbf{1}_N$) that the project is good, after receiving signals $\overline{\boldsymbol{s}}_k$ and $\boldsymbol{i}$, equals $\underline{q}$ in (4). Clearly, the higher the skill levels of the VCs in syndicate $\boldsymbol{i}$, the stronger the negative impact of signal $\boldsymbol{i}$ on the updated beliefs of $\boldsymbol{k}$.[17]

Move backward to when the early-round syndicate $\boldsymbol{i}$ decides to make a follow-on offer or not. Inside VCs have firsthand information of transparency φ and the syndicate receives signal $\boldsymbol{s}_i$ at date 2. Suppose that $\boldsymbol{s}_i$ is the all-high signal $\overline{\boldsymbol{s}}_i$. This is the only case where the syndicate considers offering follow-on financing. Both $\boldsymbol{i}$ and the entrepreneur know that if the entrepreneur refuses the follow-on financing offer of $\boldsymbol{i}$, her reservation strategy consists of seeking financing from an outside syndicate $\boldsymbol{k}$ with highest skill levels. Then $\boldsymbol{i}$ makes a Stackelberg leader follow-on financing offer that leaves the entrepreneur marginally better off than following her reservation strategy and she accepts the offer.

Now, as described above, the value of the entrepreneur's reservation strategy is directly related to $\underline{q}$, the updated belief at date 2 of the outside syndicate $\boldsymbol{k}$. So the early-round syndicate informationally holds up the entrepreneur, in that $\boldsymbol{i}$ benefits from the negative impact its nonparticipation would have on the entrepreneur, through $\underline{q}$. The share of the project return that syndicate $\boldsymbol{i}$ extracts from the entrepreneur at date 2 (the extent of the holdup) is commensurate to the skill levels $\boldsymbol{\alpha}_i$ of the VCs in $\boldsymbol{i}$: Proposition 1 states that syndicate $\boldsymbol{i}$ makes a date-2 offer $R_2 = \rho - \left(\rho - \frac{1-\gamma}{\underline{q}}\right)\underline{p}^N$.

Move finally to the early round of investment. At date 1, the entrepreneur chooses which early-round syndicate $\boldsymbol{i}$ to approach. She faces a trade-off. On the one hand, the higher the skill levels $\boldsymbol{\alpha}_i$, the higher the syndicate's ex ante valuation of the project. Then, the more attractive the early-round competitive offer this syndicate can make. On the other hand, whoever finances the early-round at date 1 will hold her up at date 2 and the higher the VC skill levels $\boldsymbol{\alpha}_i$, the larger the extent of the holdup.

[17] $\underline{q}$ is decreasing in α_{i_n}, for all $n \in \{1, \ldots, N\}$, through J in (5).

We show that although the syndicate could offer extra funds in the early round (to contain the extent of the holdup in the follow-on round), doing so does not serve best the entrepreneur. The date-1 offer which provides the highest payoff to the entrepreneur is such that only the minimum required investment γ is made, that is, $D_1 = 0$ and $I_1 = \gamma$. Providing an immediate dividend to the entrepreneur or funds in excess of γ is not helpful because it destroys the value of the option-like advantage of staged investments. We show that committing extra funds destroys more option value than it limits the holdup problem.

Proposition 1 states that the entrepreneur's best choice of early-round syndicate belongs to the set of syndicates $\boldsymbol{\mathcal{S}} = \{(i_1,\ldots,i_N) \,|\, V_{\mathbf{i},1} = 0 \text{ for } R_1 = 0\}$. A syndicate $(i_1,\ldots,i_N)$ is within $\boldsymbol{\mathcal{S}}$ when its' expected payoff at date 1 equals 0, if it demands nothing to the entrepreneur at date 1 (the early-round contracted repayment R_1 is set to 0). Clearly, expected payoffs at date 1 take into account that the syndicate will hold up the entrepreneur at date 2. The skill levels of a syndicate in $\boldsymbol{\mathcal{S}}$ are such that the expected value from holding up the entrepreneur at date 2 just compensates the expected investment costs of the syndicate.[18] Such a syndicate provides the entire value of the project to the entrepreneur at date 1.

A more skilled early-round syndicate increases the valuation of the project, but is more threatening in the follow-on round. Then, an early-round syndicate that consists of most skilled VCs is unattractive due to the following. The incumbent syndicate is the best informed in the follow-on round. If it consists of most skilled VCs, it is also the most accurate. So if it does not finance the follow-on round, no alternative syndicate is willing to take over. The incumbent syndicate can then capture the full value of the project. As shown in Appendix B of the Supplementary Material:

Lemma 1 (intermediacy). The early-round syndicate $\boldsymbol{i}$ has skill levels $\boldsymbol{\alpha}_i \lneqq \mathbf{1}_N$.

Lemma 1 states that the set $\boldsymbol{\mathcal{S}}$ consists of syndicates whose aggregate skill level is *intermediate.* The condition $V_{\mathbf{i},1} = 0$ for $R_1 = 0$ characterizes this optimal intermediate aggregate skill level.

Pushing further, we establish a "pairwise" preference for heterogeneity. Consider a syndicate $\boldsymbol{i} \in \boldsymbol{\mathcal{S}}$. Take two VCs i_n and i_m in $\boldsymbol{i}$. Denote $\boldsymbol{i}^-$ the $N-2$ other VCs in $\boldsymbol{i}$, so that syndicate $\boldsymbol{i} = (i_n, i_m, \boldsymbol{i}^-)$. Fix the $N-2$ VCs $\boldsymbol{i}^-$ and consider the set $\boldsymbol{\mathcal{P}}(\boldsymbol{i}^-) \equiv \{(i_n,i_m) \,|\, (i_n,i_m,\boldsymbol{i}^-) \in \boldsymbol{\mathcal{S}}\}$ of VC pairs (i_n,i_m) such that condition $V_{\mathbf{i},1} = 0$ holds. We show in Appendix C of the Supplementary Material that:

Lemma 2 (heterogeneity). Running along pairs $(i_n,i_m) \in \boldsymbol{\mathcal{P}}(\boldsymbol{i}^-)$, both i) the updated belief of the outside syndicate $\boldsymbol{k}$ at date 2, $\underline{q}$ in (4), and ii) the entrepreneur's payoff at

[18] Bergemann and Hege (1998), Cornelli and Yosha (2003), Repullo and Suarez (2004), and Yung (2019) develop theories built on the option-like advantage of staging to explain the extensive usage of convertible securities by VCs in the United States documented by Kaplan and Strömberg (2003) and Kaplan and Strömberg (2004). We have little to contribute to the literature explaining the usage of standard terms (debt, equity, and convertible) in VC financing. The focus of our study is on the characterization of the early and the follow-on syndicate. In our model, there is only one possible project return ρ at date 3, in case the entrepreneur exerts effort and the project is a success. The level of entrepreneurial effort and the VCs actions do not alter the probability that the project is good.

date 1, $V_{e,1}$ in (3), increase in $|\alpha_{i_n} - \alpha_{i_m}|$. This holds for any syndicate $\boldsymbol{i} \in \boldsymbol{\mathcal{S}}$, fixing any $\boldsymbol{i}^-$ within $\boldsymbol{i}$.

Lemma 2 establishes that the larger the difference between the levels of skills of any two VCs in the inside syndicate $\boldsymbol{i}$, the larger $\underline{q}$ and $V_{e,1}$. There is a preference for *heterogeneity*: Other things being equal, homogeneity is undesirable; on the contrary, maximum heterogeneity is desirable.

Note that Lemma 2 is only a pairwise result. Therefore, if $N \geq 3$, it does not permit to completely solve for $\boldsymbol{\alpha}_i$. For pair syndicates ($N = 2$), however, condition $V_{\mathbf{i},1} = 0$ and Lemma 2 are sufficient to fully determine $\boldsymbol{\alpha}_i$. We show in Appendix D of the Supplementary Material that:

Proposition 2. If $N = 2$, the early syndicate $\boldsymbol{i} = (i_1, i_2)$ is such that VC i_1 has the highest possible skill level $\alpha_{i_1} = 1$, and VC i_2 has an optimally reduced skill level $\alpha_{i_2} = \tilde{\alpha}$ where

$$\tilde{\alpha} \equiv \frac{b - \sqrt{b^2 - 4ac}}{a\overline{p}\varphi} - \frac{1}{\varphi}, \tag{6}$$

$$\text{with} \quad a \equiv (-1+\gamma+\rho)\pi\left(1-\underline{p}^2\right) + (1-\gamma)(1-\pi)\left[1-\left(1-\underline{p}\right)^2\right](1-\overline{p})/\overline{p}, \tag{7}$$

$$b \equiv a + c + (1-\gamma)(1-\pi)\left(1-\underline{p}\right)^2[\overline{p} + (1-\overline{p})/\overline{p}], \tag{8}$$

$$c \equiv \gamma + (1-\gamma)(1-\pi)(1-\overline{p}), \tag{9}$$

$$\overline{p} \equiv p_{i_n}\big|_{\alpha_{i_n}=1} = \frac{1+\varphi}{2}. \tag{10}$$

The case of pair syndicates ($N = 2$) is very helpful: Developing the understanding is easiest with two dimensions. To illustrate, we consider a numerical example with the following input parameters: $\pi = 20\%$, $\gamma = 20\%$, $\rho = 3$, $\varepsilon = 0.001$, $\varphi = 90\%$, and $\theta = 50\%$.

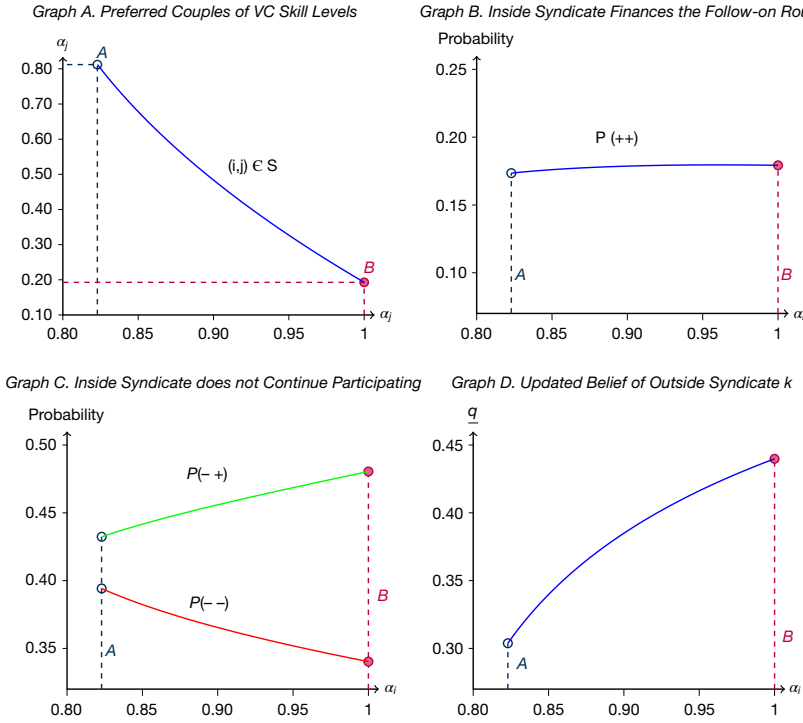
The skill levels, α_{i_1} and α_{i_2}, of VC couples (i_1, i_2) in the set $\boldsymbol{\mathcal{S}}$ are illustrated in Graph A of Figure 1. The set $\boldsymbol{\mathcal{S}}$ starts from a homogeneous syndicate (i_1, i_2) where $\alpha_{i_1} = \alpha_{i_2}$. This corresponds to point A in the figure. The set runs down to a most heterogeneous syndicate (i_1, i_2) where α_{i_1} and α_{i_2} are most distinct. This most heterogeneous syndicate is such that $(\alpha_{i_1}, \alpha_{i_2}) = (1, \tilde{\alpha})$, where the analytical expression of $\tilde{\alpha}$ is given in (6). This corresponds to point B in the figure. Pairs $(\alpha_{i_1}, \alpha_{i_2})$ along the curve have the optimal intermediate aggregate skill level.

A syndicate (i_1, i_2) makes a competitive offer at date 1 and then finances the follow-on round only if the signal $\boldsymbol{s}_i$ it receives at date 2 is the all-high signal $\overline{\boldsymbol{s}}_i$. With $N = 2$, the all-high signal consists of two positive signals, $\overline{\boldsymbol{s}}_i = (\overline{s}_{i_1}, \overline{s}_{i_2})$. Syndicates in $\boldsymbol{\mathcal{S}}$ have the optimal intermediate aggregate skill level. Therefore, they are about equally likely to finance the follow-on round. Graph B of Figure 1 illustrates that syndicates in $\boldsymbol{\mathcal{S}}$ have about the same probability of receiving two positive signals, $P(++) \equiv P(\overline{s}_{i_1}, \overline{s}_{i_2})$.

FIGURE 1

Early-Round Heterophily

Graph A of Figure 1 shows the combinations of VC skill levels such that the expected payoff at date 1 of the early-round syndicate equals 0 ($V_{i,1}=0$). Among these VC pairs, pair A corresponds to a homogeneous syndicate ($(\alpha_{i_1},\alpha_{i_2})$ where $\alpha_{i_1}=\alpha_{i_2}=0.8229$) and pair B to a most heterogeneous syndicate ($(\alpha_{i_1},\alpha_{i_2})=(1,\bar{\alpha})$ where $\bar{\alpha}=0.1928$). Graph B shows the probability an early-round syndicate $(i_1,i_2)\in\boldsymbol{\mathcal{S}}$ receives two positive signals, $P(++)\equiv P(\overline{s}_{i_1}\cap\overline{s}_{i_2})$. If this occurs, (i_1,i_2) finances the follow-on round. Graph C shows the probability an early-round syndicate $(i_1,i_2)\in\boldsymbol{\mathcal{S}}$ receives one positive and one negative signal, $P(-+)\equiv P(\overline{s}_{i_1}\cap\underline{s}_{i_2})+P(\underline{s}_{i_1}\cap\overline{s}_{i_2})$, and the probability it receives two negative signals, $P(--)\equiv P(\underline{s}_{i_1}\cap\underline{s}_{i_2})$. If one of these occurs, (i_1,i_2) does not finance the follow-on round. Graph D shows $\underline{q}$ in (4), the updated probability of an syndicate with highest skill levels $\boldsymbol{k}=(k_1,k_2)$ such that $(\alpha_{k_1},\alpha_{k_2})=(1,1)$, that the project is good, after receiving two positive signals ($\overline{s}_{k_1}$ and $\overline{s}_{k_2}$), and the negative signal of non-continued participation of the early-round syndicate (i_1,i_2). $\underline{q}$ is shown for all early-round syndicates $(i_1,i_2)\in\boldsymbol{\mathcal{S}}$. Input parameters: $\pi=20\%$, $\gamma=20\%$, $\rho=3$, $\varepsilon=0.001$, $\varphi=90\%$, and $\theta=50\%$.



By complement, all syndicates in $\boldsymbol{\mathcal{S}}$ are about equally likely to not participate to the follow-on round of financing (to receive either $\boldsymbol{s}_i=(\underline{s}_{i_1},\overline{s}_{i_2})$ or $\boldsymbol{s}_i=(\overline{s}_{i_1},\underline{s}_{i_2})$ or $\boldsymbol{s}_i=(\underline{s}_{i_1},\underline{s}_{i_2})$). However, among syndicates in $\boldsymbol{\mathcal{S}}$, the most heterogeneous syndicate is the one most likely to receive only one negative signal ($\boldsymbol{s}_i=(\underline{s}_{i_1},\overline{s}_{i_2})$ or $\boldsymbol{s}_i=(\overline{s}_{i_1},\underline{s}_{i_2})$) and least likely to receive two negative signals ($\boldsymbol{s}_i=(\underline{s}_{i_1},\underline{s}_{i_2})$). Graph C of Figure 1 shows the probability that a syndicate $(i_1,i_2)\in\boldsymbol{\mathcal{S}}$ receives one positive and one negative signal, $P(-+)\equiv P(\overline{s}_{i_1},\underline{s}_{i_2})+P(\underline{s}_{i_1},\overline{s}_{i_2})$, and the probability that it receives two negative signals, $P(--)\equiv P(\underline{s}_{i_1},\underline{s}_{i_2})$. $P(--)$ decreases and $P(-+)$ increases, as the syndicate is more heterogeneous (gliding from A to B).

It follows that nonparticipation to the follow-on round of a most heterogeneous inside syndicate sends a milder negative signal to outsiders. It therefore influences less negatively the updated belief of the outside syndicate $\boldsymbol{k}$ that the

project is good, $\underline{q}$ in (4). Lemma 2 establishes this formally. Considering all possible early-round syndicates $(i_1, i_2) \in \boldsymbol{\mathcal{S}}$, Lemma 2 establishes that $\underline{q}$ increases with the absolute difference between the skill levels of VCs i_1 and i_2 (i.e., α_{i_1} and α_{i_2}). Graph D of Figure 1 shows $\underline{q}$, for all syndicates $(i_1, i_2) \in \boldsymbol{\mathcal{S}}$. The updated belief $\underline{q}$ is highest when the early-round syndicate is most heterogeneous (corresponding to point B).

So, among early-round syndicates in $\boldsymbol{\mathcal{S}}$, a most heterogeneous syndicate gives the entrepreneur the biggest chance of obtaining alternative follow-on financing, should she need it. The value of the entrepreneur's reservation strategy in the follow-on round is then highest. As a result, the entrepreneur's expected payoff at date 1, $V_{e,1}$ in (3), is highest selecting a most heterogeneous early-round syndicate. Proposition 2 states the entrepreneur's preference for an early-round syndicate with most heterogeneous skill levels: The early syndicate $\boldsymbol{i} = (i_1, i_2)$ is such that $(\alpha_{i_1}, \alpha_{i_2}) = (1, \tilde{\alpha})$, where $\tilde{\alpha}$ is given in (6). From Lemma 1, the skill level $\tilde{\alpha}$ is reduced in that it is strictly smaller than 1. Clearly, the lower $\tilde{\alpha}$, the more the two VCs constituting the early-round syndicate have heterogeneous skill levels.

The extent to which $\tilde{\alpha}$ is lower than 1 is determined by the magnitude of the differential information between the inside syndicate and outsiders. The outsiders' disadvantage is large when the factor θ takes a small value. In Appendix E of the Supplementary Material, we show that $\tilde{\alpha}$ is strictly increasing in θ. This yields the following testable hypothesis:

Hypothesis 1. The heterogeneity of VC skill levels in early-round syndicates should be positively related to the informational disadvantage of outsiders.

The fact that the second early-round VC has reduced skill level has an implication on the likelihood an alternative syndicate accepts to finance the follow-on round. In Appendix F of the Supplementary Material, we show that the probability that a switching of syndicate occurs in the follow-on round is strictly positive. This feature comes from the holdup by the VC syndicate. Absent this holdup, the classic result that VC skill is monotonically desirable holds, and no syndicate switching occurs.[19]

The dynamics of heterogeneity and switching are then related: The probability of syndicate switching in the follow-on round is strictly decreasing in $\tilde{\alpha}$. A more heterogeneous early-round syndicate increases the likelihood that the outside syndicate finances the follow-on round because it enhances the updated belief of the outside syndicate that the project is good after the nonparticipation of the inside syndicate. This yields the following testable hypothesis:

Hypothesis 2. The frequency of syndicate switching in follow-on rounds should be positively related to the heterogeneity of VC skill levels in the earlier round syndicate.

[19] As already mentioned, we solve in Appendix G of the Supplementary Material the model under the alternative polar-case assumption that the informational advantage *does not* increase the bargaining power of the inside syndicate vis-a-vis the entrepreneur in the follow-on round. The equilibrium outcome in the absence of holdup is such that i) both i_1 and i_2 have the highest skill levels and ii) if syndicate (i_1, i_2) does not finance the follow-on round, no one finances it.

III. Data Description and Variables

A. Data Source and Sample

We take the theory to the data using data extracted from PitchBook. The initial sample covers financing rounds of U.S.-headquartered entrepreneurial firms between 2007 and 2020. PitchBook provides comprehensive coverage of VC investment deals since 2007. As a relatively new comer in VC data suppliers, PitchBook has the advantage of broader coverage in recent years.[20]

The data provide detailed information on VC investments, which includes the dates and investment amounts for different financing rounds, the identities of investing VC firms, development stages and industry groups of entrepreneurial firms, locations and founding dates of entrepreneurial firms, and the dates and types of an exit (e.g., IPO, acquisition, or liquidation). Another advantage of PitchBook over other data sets is that it reports detailed information about educational and professional experience for founding team members of those VC-backed ventures as well as for individual VC investors. In addition, to account for historical investment experience of VC firms prior to the year 2007, we further supplement data from Thomson One that covers investments taking place since 1975.

In constructing the sample, we start with all the VC funding rounds taking place in the United States in a 5-year window from 2010 to 2014. By starting the sample in 2010, we leave at least 3 years since 2007 to accumulate prior investment experience by VC firms.[21] The sample ends in 2014, as we collect information on exit events through Feb. 2021 and thus allow for at least 6 years to identify the final outcome of investing in a given entrepreneurial firm.[22]

We further restrict the sample to VC deals that involve at least one conventional VC investor. As noted in Ewens, Rhodes-Kropf, and Strebulaev (2016), such an investor raises fixed life funds and finances new businesses that usually combine risk with potential for high returns. Those investors are categorized as "Venture Capital" or "SBIC" in PitchBook. Hedge funds, mutual funds, buyout funds, venture capital arms of corporations, and regional development corporations are excluded from this definition.[23] Moreover, we focus on venture capital deals and exclude investment deals labeled as "Angel," "Incubator/Accelerator,"

[20]In the Appendix, we compare data coverage between PitchBook and Thomson One's Venture One by counting the distinct number of funding rounds recorded in each data source with disclosed round amounts for the period of 2007 to 2014. PitchBook starts to have more coverage than Thomson One since 2009, and its coverage advantage has been increasing over years, with twice number of deals covered than Thomson One for the year 2014.

[21]When building VC experience measures, in addition to PitchBook data, we also make use of data extracted from Thomson One to supplement information on historical investments made by VC firms between 1975 and 2007. Section III.B describes the details.

[22]We use exit outcome in Probit estimation that generates probability of a "good exit" of an entrepreneurial firm at the time of a funding round. Following Cumming and Dai (2013), we include such predicted probability as a control in our testing of Hypothesis 2, as explained in Section IV.B.

[23]Although diversified private equity funds also invest in VC deals, we are not able to identify this particular type of investor as PitchBook group private equity and buyout funds in the same category of investor type. Nevertheless, our results remain robust when we include in the sample deals involving investors of the type of buyout/private equity. We adopt a strict definition of conventional VC investors in the analysis reported in the paper.

or "Grant." Following Ewens, Gorbenko, and Korteweg (2022), we also excluded the first rounds with financings greater than $100 million, as they are more likely to involve non-VC-backed startups.

We exclude deals that are likely affected by a "friends and family effect." In the early stage of development, founders of young entrepreneurial firms likely go to their friends or family before resorting to outside sources for funding support. For entrepreneurial firms who successfully obtain funding from friends or family with deep pockets, there is low dispersion among the participating investors and those investors are also likely to continue investing in the venture. This is also consistent with the observations of VC heterogeneity in early rounds and switching of investors in later rounds. To ensure our main results are not driven by a "friends and family effect," in addition to excluding all the deals labeled as "Angel (Individual)" or involving any undisclosed individual investors, we apply the following steps in constructing the sample. First, we exclude all rounds with rather small amounts of investment. Specifically, we only consider rounds with investment size of at least $100,000.[24] Second, we drop all rounds in which at least one participating entity has only limited investment activities. We examine comprehensive data of VC investments in the United States from 2007 to 2021, and identify institutions that have invested in only one single entrepreneurial firm in the entire period. We suspect those institutions have personal connections with founders of their only investee firms, and thus we remove all rounds that received funding from any of those institutions. Last, we exclude rounds in which individual investors and founders likely form connections through their previous educational or professional experience. We first remove all the rounds in which at least one participating VC investor attended one same university with a member on the founding team of the entrepreneurial firm. In detecting alumni connections, for each individual, we examine all levels of education since their undergraduate study.[25] Moreover, we drop all rounds in which an individual investor and a member on the founding team were professionally affiliated with one same organization prior to the focal round. To track those professional connections, we consider a variety of professional roles previously taken by founders and investors, including employee, founder, board member, and advisor.[26]

In our empirical analysis, we examine if heterogeneity of VC skill levels in syndicates arise in response to potential informational holdup by incumbent VC firms. Accordingly, we consider syndicated deals that involve at least two VC firms. In testing Hypothesis 1, our sample contains 12,128 VC funding rounds raised by

[24]This threshold value is about 7th percentile of deal size of all rounds in our data. Our results remain robust to using other threshold values for investment sizes (such as $120,000 and $50,000).

[25]In the sample period from 2010 to 2014, our data contain information of at least one educational degree for at least one founding team member (VC partner) for 82% (73%) of VC deals received by U.S. entrepreneurial firms. In total, we find 6,267 distinct pairs of individual VC investors and start-up founding team members that went to one same university and were also affiliated with one same investment deal.

[26]Our data contain information of at least one position at an organization different from a focal venture and with a disclosed start date prior to a focal deal for at least one founding team member (VC partner) for 33% (73%) of VC deals received by U.S. entrepreneurial firms. In total, we find 1,334 distinct pairs of individual VC investors and start-up founding team members that were previously affiliated with one same organization that is different from the focal venture.

8,727 U.S. entrepreneurial firms between 2010 and 2014, and 8,029 of those funding rounds are backed by syndicates consisting of more than one VC firm. Furthermore, in testing Hypothesis 2, we track if entrepreneurs switch VC investors in subsequent rounds and, thus, consider entrepreneurial firms that received more than one round of funding. In our sample, there are in total 4,447 syndicated rounds that are also followed by a subsequent funding round. As a result, our analysis will be subject to bias caused by selection due to syndication as well as due to survivorship to next rounds. We therefore control for selection in our study.

B. Experience Heterogeneity in VC Syndicates

We use investment experience as a proxy for VC firms' skill level and count prior investment rounds of a VC firm. This measure is consistent with previous literature (Sørensen (2007), Nahata (2008), and Hong, Serfes, and Thiele (2020)). As PitchBook starts comprehensive coverage of VC investments only since year 2007, we supplement historical investment records of VC firms prior to 2007 using data from Thomson One that dates back VC investments to the year 1975. Hence, we measure VC firm experience by counting their investments made since 1975 to the time of a focal investment.

For each syndicated round, we measure heterogeneity of experience levels in the syndicate using two alternative measures: i) coefficient of variation (CV) of VC experience levels and ii) GINI coefficient of VC experience levels.

Suppose that a VC syndicate consists of N VC firms with measures of experience $x_1, x_2, \ldots, x_N$. The coefficient of variation of VC experience levels of this syndicate is the ratio of the standard deviation to the mean of the N experience levels, normalized by a factor of $1/\sqrt{N-1}$:

$$CV \equiv \frac{\sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(x_i - \left(\frac{1}{N}\sum_{i=1}^{N} x_i\right)\right)^2}}{\frac{1}{N}\sum_{i=1}^{N} x_i} \frac{1}{\sqrt{N-1}}. \tag{11}$$

The GINI coefficient of VC experience levels is half the ratio of the average absolute difference of all pairs to the mean of the N experience levels, normalized by a factor $N/(N-1)$:

$$\text{GINI} \equiv \frac{1}{2} \frac{\frac{1}{N^2}\sum_{i=1}^{N}\sum_{j=1}^{N}|x_i - x_j|}{\frac{1}{N}\sum_{i=1}^{N} x_i} \frac{N}{N-1}. \tag{12}$$

Normalization ensures that the coefficients lie between 0 and 1, for any number of partners in the syndicate.[27] In the event that all VC firms have a measure of experience equal to 0, which represents less than 1% of the observations, we assign a value of 0 to CV and GINI.

[27]The ratio of the standard deviation to the mean of N nonnegative numbers lies between 0 and $\sqrt{N-1}$. Half the ratio of the average absolute difference of all pairs to the mean of N nonnegative numbers lies between 0 and $(N-1)/N$. In both cases, the maximum value is reached when one number is strictly positive and all others are equal to 0. See Katsnelson and Kotz (1957). Deltas (2003) shows that normalizing a GINI coefficient by a factor $N/(N-1)$ also eliminates small sample downward bias.

TABLE 1

Syndicate Heterogeneity from Simulation

In Table 1, holding the size of VC syndicate fixed, we perform 1,000 runs of simulations, and in each run, 500 syndicates are formed. We assume that experience of VC firms that potentially seek for investment opportunities is subject to a uniform distribution. We report the summary statistics of the means of coefficient of variation (CV) and GINI produced by simulations.

No. of VCs in a Syndicate	Mean ($\overline{\text{CV}}$)	Std. Dev. ($\overline{\text{CV}}$)	Mean ($\overline{\text{GINI}}$)	Std. Dev. ($\overline{\text{GINI}}$)
2	0.386	0.012	0.386	0.012
3	0.414	0.010	0.370	0.008
4	0.342	0.007	0.361	0.007
5	0.297	0.005	0.356	0.006
6	0.266	0.004	0.352	0.005
7	0.242	0.003	0.350	0.005
8	0.223	0.003	0.347	0.004
9	0.210	0.002	0.346	0.004
10	0.196	0.002	0.345	0.004

When is a CV and GINI coefficient value small or large? Shall we expect values to be close to 0.5? To have sense of this, assume i) that the VC firms available for investment have levels of experience which are uniformly distributed over the interval $[0,1]$ and ii) that any syndicate of N VCs is formed drawing randomly and independently N VC firms from this pool of available firms.[28] The expected values of the CV and GINI coefficients in this purely agnostic case provide helpful benchmark values.

We perform simulations to estimate these expected values. Holding N fixed, we perform 1,000 runs of simulations and in each run 500 syndicates of N VCs are formed. For each syndicate of N VCs, the VC firm experience levels $x_1, x_2, \ldots, x_N$ are random numbers from the uniform distribution on the interval $[0,1]$. In Table 1, we present the summary statistics of the means of CV and GINI (i.e., $\overline{\text{CV}}$ and $\overline{\text{GINI}}$), for N ranging from 2 to 10. The means of $\overline{\text{GINI}}$ fall in a narrow range between 0.345 and 0.386, whereas the means of $\overline{\text{CV}}$ range between 0.196 and 0.414.

We turn to examining the levels of VC heterogeneity presented in the data. Panel A of Table 2 reports means and medians for CV and GINI coefficients in syndicated rounds. Overall, compared with the results from simulations of randomly formed syndicates, our sample shows a much higher level of heterogeneity of VC syndicates, as suggested by a mean of 0.74 for coefficient of variation, as well as a mean of 0.66 for GINI coefficient (see column 1 in Panel A of Table 2). Furthermore, columns 3–10 present a comparison across rounds of different sequence numbers: Later rounds have lower heterogeneity than earlier rounds, with the first-round syndicates showing the highest coefficients (i.e., CV and GINI) at both median and mean levels.

C. Switching

We track if *all* investing VC firms in a syndicated round discontinue investment in later rounds, conditional on the entrepreneurial firm receiving a subsequent

[28] Equivalently, assume that the available VC firms have levels of experience which are uniformly distributed over the interval $[0,\bar{x}]$, where $\bar{x}$ is an upper bound to experience levels. The results do not depend on $\bar{x} \in \mathbb{R}_{>0}$, so we can simply set the upper bound to 1.

TABLE 2

Heterogeneity of VC Syndicates and Switching of VC Syndicates

Panel A of Table 2 presents the patterns of heterogeneous VC syndicates for rounds of different sequence numbers. VC firms' experience counts the number of investment rounds a VC firm participated since 1975 to a focal round. Within each syndicated round, we calculate two alternative measures for VC experience heterogeneity: coefficient of variation (CV) and GINI coefficient. Panel B reports the rates of *all* investing VC firms in a round no longer participating in any of the subsequent rounds, given an entrepreneurial firm survived to receive at least one subsequent round (i.e., ALL_SWITCH). Only syndicated rounds that survived to a subsequent round are included in the sample for generating the statistics in Panel B. For each group of rounds with a sequence number later than the first (i.e., second, third, fourth, and later rounds), we perform a mean equality test with the first-round group sample and present the *p*-values from those tests in columns 4, 6, and 8.

Panel A. VC Heterogeneity in Syndicated Deals

	All Rounds		First Round		Second Round		Third Round		Fourth and Later Rounds	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
	1	2	3	4	5	6	7	8	9	10
CV	0.74	0.68	0.78	0.74	0.74	0.70	0.72	0.67	0.71	0.65
GINI	0.66	0.70	0.67	0.73	0.66	0.70	0.65	0.68	0.67	0.69
No. of obs.	8,029		1,779		1,985		1,508		2,757	

Panel B. Switching of VC Syndicates

	All Rounds	First Round	Second Round		Third Round		Fourth and Later Rounds	
	Mean	Mean	Mean	*p*-Value	Mean	*p*-Value	Mean	*p*-Value
	1	2	3	4	5	6	7	8
ALL_SWITCH	0.19	0.21	0.17	0.04	0.16	0.00	0.21	0.95
No. of obs.	4,447	874	1,133		862		1,578	

funding round. ALL_SWITCH equals 1 if *none* of the investing VC firms in the current syndicated rounds participate in *any* of the subsequent funding rounds, and 0 otherwise. As reported in Panel B of Table 2, likelihoods of nonparticipation by all investing VC firms in subsequent rounds decrease, as round sequence number goes up (except for the group of the fourth and later rounds). Furthermore, for each group with round sequence numbers later than the first (i.e., second, third, fourth, and later rounds), we perform a mean equality test with the first-round group. We find a statistically significant difference for the second- and third-round groups. For the fourth and later rounds, their switching rates are the same with the first-round group (i.e., 0.21).

We further explore the relationships between frequencies of switching and heterogeneity of VC experience in a syndicate using a simple univariate approach. For each year in our sample, we divide all investing VC firms in syndicated deals into four quartile groups by their experience levels. $Q4$ ($Q1$) represents the highest (lowest) quartile group of VC firms with respect to their experience levels. In a syndicated deal, we then consider the quartile groups that the most-experienced and the least-experienced VC firms belong to. In Table 3, we report the switching rates of *all* participating VC firms conditional on a focal entrepreneurial firm receiving subsequent funding.[29] The diagonal represents low heterogeneity. Movements 45 degrees southwest from the diagonal represent increased heterogeneity while holding average quality approximately fixed. According to the theory, such shifts reduce the chance of switching. In Table 3, this inequality indeed holds in each comparison,

[29]The top-right cells of the table are blank as the experience of the best VC firm must exceed that of the worst VC firm.

TABLE 3

Switching Rates by Syndicating VC Firms' Experience

Table 3 reports the rates of *all* investing VC firms switching by different combinations of quartile groups of VC experience in a syndicate. We consider all the syndicated deals in the U.S. VC market from 2010 to 2014 that received at least one subsequent funding round. For each year in our sample, we divide all investing VC firms into four quartile groups by their experience levels. *Q*4 (*Q*1) represents the highest (lowest) quartile group of VC firms with respect to their experience levels.

		Experience of the Worst VC			
		Q1	Q2	Q3	Q4
Experience of the best VC	Q1	0.45			
	Q2	0.44	0.35		
	Q3	0.32	0.30	0.22	
	Q4	0.20	0.18	0.16	0.10

suggesting a positive relationship between VC syndicate heterogeneity and occurrences of switching by investors in later rounds. Such results do not seem to be driven by the level of average quality of investors in a syndicate.[30]

D. Network Centrality

To quantify the extent of informational disadvantage of outsiders, we adopt a proxy for credibility of entrepreneurs to outsiders established through social networks. Part of the information generated by the early investment is soft: It cannot be fully expressed in the form of objective performance indicators or milestones and, thus, is not verifiable. The entrepreneur faces problems of credibility as she communicates information: Outside VC firms doubt that positive information they receive is true and worry that negative information is hidden from them. Through network linkages, entrepreneurs can establish credibility and legitimacy with potential investors (Stuart et al. (1999), Uzzi (1999), and Hsu (2007)). The higher this credibility, the more outside VCs consider highly information conveyed by the entrepreneur, and the lower the informational disadvantage of outside VCs.

Specifically, we draw from the literature and consider social ties built by entrepreneurial firms' founding team members through a variety of professional roles, including founders, employees, board members, and advisors. First, given the high level of clustering of high-tech entrepreneurial activities and the highly connected nature of VC communities, social interactions from prior founding experience provides means for entrepreneurs to communicate existence and quality of entrepreneurial ideas to outsiders (Stuart and Sørensen (2003), Hochberg, Ljungqvist, and Lu (2007), (2010), Kolympiris, Kalaitzandonakes, and Miller (2011), and Bubna, Das, and Prabhala (2020)). Through observing the track records of prior founding attempts, outsiders access information useful for evaluating the quality of a new venture (Sit-in (1992), Kaplan and Strömberg (2003), and Hsu (2007)). Second, prior employment experience engenders social ties that can facilitate flows of information, which in turn benefits resource acquisition for new ventures (Gompers, Lerner, and Scharfstein (2005)). This results in information and status advantages for entrepreneurs with career experience at prominent

[30]In Table A.I in Appendix H of the Supplementary Material, we compare characteristics of entrepreneurial firms that experienced switching of VC firms and those that did not.

established firms, reducing the "perceived uncertainty of a venture" and leading to higher likelihoods of obtaining funding (Burton, Sørensen, and Beckman (2002), Shane and Stuart (2002)).

We therefore consider networks consisting of social ties originated from prior career experience of founding team members. The data contain in total 32,821 people (i.e., founding team members of VC-backed ventures) affiliated with 20,150 organizations with a variety of professional roles including founders, employees, advisors, and board members. We leverage on the rich information in the data regarding the exact dates that each person starts or ends their professional roles in an organization. For each year in the period from 2010 to 2014, we construct a network where nodes represent organizations that are either VC-funded entrepreneurial firms, or other firms that those entrepreneurial firms' founding team members are previously or currently affiliated with professionally. A link between two nodes forms as one person has taken professional roles in two organizations. Our network construction is similar to Bonaventura, Ciotti, Panzarasa, Liverani, Lacasa, and Latora (2020) that build a worldwide network of professional relationships among entrepreneurial firms. However, our approach differs in that we do not consider professional relationships of VC partners who invest in an entrepreneurial firm, as we seek to capture social capital owned by entrepreneurial firms. Graph A of Figure 2 illustrates as an example the network connections owned by the entrepreneurial firm Avoided, at the time of its first funding round, showing the direct ties originated from founding and employment relationships of its affiliated key personnel.

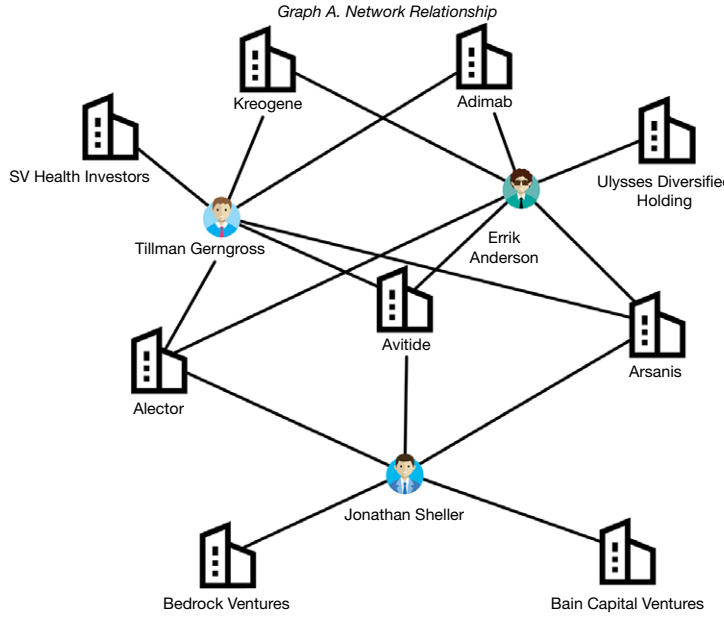
The network is time-varying to reflect the occurrences of the following events: i) A new company is founded, ii) a person starts affiliation with a new organization, or iii) a person leaves his/her position in an entrepreneurial firm. Once created, a link is maintained in the network for all subsequent years of analysis. Moreover, in the event of departure by a founding team member, all links associated with the departing member will be removed afterward. As a result, our network describes dynamically updating social ties for U.S.-headquartered entrepreneurial ventures. Graph B of Figure 2 plots the number of nodes and edges contained in each year's network. Graph C presents by year the ratio of number of nodes in the largest connected component (LCC) over the total number of nodes in the network. Such ratio grows by year and reaches a level of 0.13 in 2014. A high ratio of number of nodes in the LCC over total number of nodes in the network suggests a high level of connectedness of all the firms contained in the network.

We use closeness centrality as a proxy for the extent to which insiders have informational advantage over outside investors. By definition, the closeness centrality calculates the average of the shortest paths from a node to all other nodes in the network (Wasserman and Faust (1994)). Existing literature suggests actors with high closeness centrality scores are very productive in communicating information to other actors in the network (Freeman (1978), Beauchamp (1965)). Therefore, closeness centrality measure captures the easiness for information to flow and thus the ability of entrepreneurial ventures to build credibility to outsiders. This well serves our purpose to quantify informational advantage of insiders over outsiders: Entrepreneurial firms with lower closeness centrality scores suffer from lower credibility to outsiders, and thus their inside investors enjoy more privileged access

FIGURE 2

Description of Entrepreneurial Network

Graph A of Figure 2 illustrates an example of the network relationships owned by the entrepreneurial firm Avoided. Only direct ties of relationships are presented. Before Avitide's first round in Mar. 2013, one of the co-founders, Tillman Gerngross, who was previously affiliated with SV Health Investors, has founded a series of other companies, including Adimab (in 2007), Kreogene (in 2008), Arsanis (in 2010), and Alector (in Jan. 2013). Mr. Gerngross' partners from those previously founded ventures, namely Errik Anderson and Jonathan Sheller, also joined him in founding Avoided. In addition, Mr. Anderson himself founded Ulysses Diversified Holdings in 1994, and Mr. Sheller used to work at Bain Capital Ventures, and then left in 2011 to found Bedrock Ventures. All of those prior professional relationships owned by the key personnel are described in the figure. Graph B shows the number of edges and nodes in each year's network from 2010 to 2014. Graph C plots the ratio of the number of nodes in the largest connected component and the total nodes in each year's network.



to information than outsiders. Formally, we follow Wasserman and Faust (1994)[31] and calculate closeness centrality score of node u at time t as follows:

$$\text{CLOSENESS\_CENTRALITY}_{ut} = \frac{n_t - 1}{N_t - 1} \frac{n_t - 1}{\Sigma_{v=1}^{n_t - 1} d(u,v)}, \tag{13}$$

[31]As introduced in Wasserman and Faust (1994), this is an "improved" closeness centrality that presents actor-level index when actors in a network are not all strongly connected.

where $d(u,v)$ is the distance between nodes u and v, N_t is the total number of nodes in the network, and n_t is the number of nodes that u can reach.

IV. Empirical Analysis

A. Heterogeneity of VC Experience Levels in Syndicates and Network Centrality of Entrepreneurial Firms

In this section, we test Hypothesis 1 and examine the relationship between outside VCs' informational disadvantage and heterogeneity of VC experience levels in syndicates (Table 4). As introduced in Section III.D, we use network centrality as a proxy for informational disadvantage of outside investors relative to insiders. We perform the estimation using the following specification:

TABLE 4

Summary Statistics

Table 4 presents the summary statistics of variables by rounds of different sequence numbers. Panel A presents statistics related to syndicated funding rounds contained in the sample for testing Hypothesis 1, and Panel B reports statistics for sample in testing Hypothesis 2 where we consider syndicated deals that are also followed by a subsequent funding round. Panel C reports statistics for all rounds (i.e., syndicated and standalone together). Table A.II in Appendix H of the Supplementary Material presents the descriptions of all variables used in the analysis.

	First Round			Second Round			Third Round			Fourth and Later Rounds		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
	1	2	3	4	5	6	7	8	9	10	11	12
Panel A. Syndicated Deals												
CV	0.78	0.74	0.38	0.74	0.70	0.34	0.72	0.67	0.33	0.71	0.65	0.32
GINI	0.67	0.73	0.27	0.66	0.70	0.24	0.65	0.68	0.24	0.67	0.69	0.22
CLOSENESS_CENTRALITY	0.001	0.000	0.002	0.001	0.000	0.003	0.001	0.000	0.003	0.001	0.000	0.004
COMPANY_AGE	1.93	1.00	3.06	3.00	2.00	3.91	4.26	3.00	4.69	7.19	6.00	4.29
DEALSIZE ($M)	4.18	1.70	7.86	6.96	3.22	13.27	10.89	6.00	19.64	21.82	10.27	56.63
GVC_LEADER	0.01	0.00	0.07	0.00	0.00	0.04	0.01	0.00	0.07	0.00	0.00	0.06
NO_OF_VCS	4.03	3.00	3.35	4.22	3.00	3.22	4.02	3.00	2.35	4.48	4.00	2.65
EXP_OF_LEAD_VC	271.37	72.00	526.65	286.96	95.00	495.15	317.51	100.00	570.91	349.10	104.00	593.20
SEED_STAGE	0.44	0.00	0.50	0.24	0.00	0.43	0.11	0.00	0.31	0.04	0.00	0.19
EARLY_STAGE	0.50	1.00	0.50	0.66	1.00	0.48	0.54	1.00	0.50	0.20	0.00	0.40
No. of obs.	1,779			1,985			1,508			2,757		
Panel B. Syndicated Deals That Received a Subsequent Round												
ALL_SWITCH	0.21	0.00	0.41	0.17	0.00	0.38	0.16	0.00	0.37	0.21	0.00	0.41
CV	0.75	0.71	0.35	0.72	0.67	0.32	0.69	0.65	0.30	0.69	0.64	0.30
GINI	0.68	0.73	0.24	0.66	0.70	0.23	0.65	0.68	0.22	0.67	0.70	0.20
EST_GOOD_EXIT_PROB	0.10	0.08	0.08	0.13	0.11	0.09	0.16	0.14	0.11	0.24	0.21	0.16
DIS_TO_VC<50_MILES	0.81	1.00	0.39	0.76	1.00	0.43	0.75	1.00	0.43	0.69	1.00	0.46
DIS_TO_VC_50_100_MILES	0.05	0.00	0.22	0.04	0.00	0.21	0.06	0.00	0.23	0.05	0.00	0.22
FOREIGN_HQ_VC	0.28	0.00	0.45	0.30	0.00	0.46	0.32	0.00	0.47	0.35	0.00	0.48
MAX_FUND_SIZE ($M)	362.43	144.00	747.13	437.79	244.00	797.66	529.01	348.50	937.40	693.01	425.00	1293.87
MAX_VC_EXP	410.21	209.00	593.79	436.56	228.00	595.23	524.80	280.50	681.68	590.57	347.00	698.88
NO_OF_VCS	4.65	3.00	3.78	4.60	3.00	3.60	4.36	4.00	2.54	4.75	4.00	2.63
No. of obs.	874			1,133			862			1,578		
Panel C. All Deals												
SURVIVAL	0.61	1.00	0.49	0.66	1.00	0.47	0.64	1.00	0.48	0.62	1.00	0.48
SYNDICATE	0.55	1.00	0.50	0.67	1.00	0.47	0.71	1.00	0.46	0.73	1.00	0.45
IND_HHI	0.36	0.32	0.24	0.36	0.31	0.22	0.34	0.30	0.21	0.34	0.29	0.21
No. of obs.	3,261			2,942			2,134			3,791		

$$(14)\quad \text{HET(EXP)}_{evst} = \alpha + \beta_1 \text{CENTRALITY}_{evst} + \beta_2 C_{et} + \beta_3 X_{vt} + \phi_s + \tau_t + \epsilon_{evst},$$

where e, v, s, and t index the entrepreneurial firm, VC syndicate, state location of the entrepreneurial firm, and year, respectively. The dependent variable, HET(EXP)_{evst}, represents the measure for the experience-level heterogeneity of investing VC firms in a focal syndicated round, namely, coefficient of variation or GINI coefficient. CENTRALITY_{evst} represents the closeness centrality of entrepreneurial firm e in a network consisting of professional relationships owned by founding team members until year t, as introduced in Section III.D.

C_{et} represents a set of controls for the characteristics of entrepreneurial firms. We control for the maturity of an entrepreneurial firm at the time of a focal funding round by including the logged value of COMPANY_AGE and development stage dummies. COMPANY_AGE is the number of years since the foundation of the company until the time of a focal investment round. We also include SEED_STAGE and EARLY_STAGE dummies that indicate the development stage of an entrepreneurial firm at the time of a focal funding round.[32] Furthermore, we control for the industry classification of entrepreneurial firms. PitchBook uses an industry classification system comparable to the Global Industrial Classification Standard, in which entrepreneurial firms are grouped into 41 distinct industry groups. We construct dummies indicating the primary industry group that an entrepreneurial firm belongs to.

X_{vt} is a set of controls of VC firm characteristics, including i) logged number of VC investors in a focal round, ii) logged experience level of lead investor, and iii) whether the lead investor is backed by government. The lead investor plays a vital role in the consummation of a VC deal by "providing an anchor investment, setting the valuation and instilling confidence in other potential investors based on their due diligence" (PitchBook Data (2020)). The identity of lead investors is available for around 70% of the funding rounds in the entire sample. In the 30% of rounds where a flag for the lead investor is missing, we follow Ewens et al. (2022) and assume that the lead investor is the VC firm with the largest number of years since its first investment at the time of the funding round.[33] We quantify the experience of a lead VC firm using the number of prior investment rounds that a lead VC firm participated in, EXP_OF_LEAD. Furthermore, a dummy variable, GVC_LEADER indicates whether a lead VC firm is backed by government (i.e., SBIC).

Finally, we control for logged round investment size. We also include fixed effects for geographic state locations of entrepreneurial firms, ϕ_s, and fixed effects for investment year, τ_t. Standard errors are clustered at state of entrepreneurial firms.

The theory predicts that holdup of entrepreneurs by VC firms arises during the initial rounds of investments when information is particularly scarce for external investors to evaluate the potentials of an entrepreneurial firm. Therefore, we examine the relationship between closeness centrality and heterogeneous syndicates

[32]PitchBook reports the following different stages of development of firms: seed, early stage, and later stages.

[33]Unlike Thomson One, PitchBook does not provide information on investment amount contributed by each individual investor. This restrains us from following previous literature and relying on per VC firm investment amount to define leaders.

TABLE 5

Effects of Network Centrality on Heterogeneity of VC Syndicates

Table 5 reports results from estimating equation (14) in OLS using all syndicated rounds in the sample. Analysis is carried out by rounds of different sequence numbers (i.e., first, second, third, fourth, and later rounds). Columns 1–4 report results using CV as the measure for syndicate heterogeneity, whereas columns 5–8 report results using GINI as the syndicate heterogeneity measure. Standard errors are clustered at the entrepreneurial firm state level and are given in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	CV				GINI			
	First Round	Second Round	Third Round	Fourth and Later Rounds	First Round	Second Round	Third Round	Fourth and Later Rounds
	1	2	3	4	5	6	7	8
CLOSENESS_CENTRALITY	−5.4690***	−5.2650**	0.3360	0.5840	−3.6570***	−3.3390**	−0.0921	0.5700
	(1.705)	(2.142)	(2.247)	(1.653)	(1.165)	(1.596)	(1.712)	(1.187)
log(COMPANY_AGE)	0.01020	0.01480	0.04390**	0.02980*	0.00825	0.00971	0.03090**	0.01640
	(0.01330)	(0.01100)	(0.01970)	(0.01540)	(0.00972)	(0.00780)	(0.01440)	(0.01200)
log(DEALSIZE)	−0.001530	−0.031200***	0.000360	0.021200***	0.002480	−0.016900***	0.004540	0.015900***
	(0.01110)	(0.00761)	(0.00949)	(0.00612)	(0.00951)	(0.00526)	(0.00706)	(0.00461)
GVC_LEADER	0.1140	0.1720	0.0659	0.0784	0.0920	0.1000	0.0498	0.0465
	(0.1150)	(0.2300)	(0.1520)	(0.0836)	(0.0849)	(0.1630)	(0.0980)	(0.0666)
log(NO_OF_VCS)	−0.3380***	−0.3090***	−0.2830***	−0.3330***	0.0105	0.0365***	0.0731***	0.0304***
	(0.02430)	(0.01430)	(0.01250)	(0.01150)	(0.01070)	(0.00930)	(0.01130)	(0.00674)
log(EXP_OF_LEAD_VC)	0.0435***	0.0362***	0.0246***	0.0242***	0.0355***	0.0278***	0.0197***	0.0192***
	(0.00410)	(0.00317)	(0.00765)	(0.00377)	(0.00296)	(0.00214)	(0.00522)	(0.00294)
SEED_STAGE	−0.0517	−0.0296	0.0568*	0.0723	−0.0287	−0.0274	0.0355	0.0435
	(0.0408)	(0.0355)	(0.0300)	(0.0457)	(0.0320)	(0.0256)	(0.0225)	(0.0367)
EARLY_STAGE	−0.07740*	−0.02390	0.00420	0.03650***	−0.04580	−0.01550	0.00239	0.01800**
	(0.04190)	(0.02870)	(0.02490)	(0.01110)	(0.03330)	(0.02080)	(0.02010)	(0.00841)
Investment year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ENT firm state dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	1,779	1,985	1,508	2,757	1,779	1,985	1,508	2,757
Adj. R^2	0.168	0.181	0.141	0.185	0.069	0.067	0.068	0.059

by performing estimation by rounds of different sequence numbers (i.e., first, second, third, fourth, and later rounds). We estimate equation (14) using OLS and present the results in Table 5. A negative relationship between closeness centrality and VC experience-level heterogeneity arises for funding rounds of all sequence numbers, except for the latest rounds.[34] However, such relationship is statistically significant only for the first and second rounds (see columns 1 and 2 of Table 5 for results based on coefficient of variation, and columns 5 and 6 for results based on GINI).

We run robustness tests by including fixed effects of lead VC firms in estimating equation (14).[35] As discussed in the Introduction, syndicate heterogeneity may arise due to alternative explanations such as differences in opportunity costs between senior and junior VC partners or specialist VCs of different areas of expertise having systematically different levels of experience. Nevertheless, extant literature documents that lead VC firms play a key role in assembling and structuring VC syndicates (e.g., Cumming and Dai (2013), Ewens et al. (2022)), and thus

[34]In the fourth and later rounds, both measures of VC experience-level heterogeneity are positively related to closeness centrality. In the third rounds, GINI is positively related to closeness centrality (see Table 5).

[35]In the estimation, we drop GVC_LEADER as it is absorbed by the fixed effects of lead VC firms.

tastes of lead VC firms influence composition of VC syndicates. Therefore, as a robustness test, we include fixed effects of lead VC firms to control for time-invariant component of preferences of lead VC firms in selecting their syndicate partners. The results remain robust (reported in Table A.III in Appendix H of the Supplementary Material): We continue to find a negative and significant relationship between closeness centrality and VC experience-level heterogeneity for early rounds (i.e., first and second rounds).

Our OLS estimation is subject to potential sample selection bias: The dependent variable, HET(EXP), is only observable if an entrepreneurial firm receives funding from a syndicate. To correct for such bias, we perform the following 2-step Heckman procedure:

$$\text{(15a)}\quad \text{SYNDICATE}_{evst} = \mathbf{1}[\alpha + \gamma_1 \text{IND\_HHI}_{evst} + \gamma_2 C_{et} + \gamma_3 X_{vt} + \phi_s + \tau_t + \psi_{evst} \geq 0],$$

$$\text{(15b)}\quad \text{HET(EXP)}_{evst} = \alpha + \beta_1 \text{CENTRALITY}_{evst} + \beta_2 C_{et} + \beta_3 X_{vt} + \beta_4 \lambda_{evst} + \phi_s + \tau_t + \epsilon_{evst}.$$

In the first step, we estimate a selection equation by Probit that uses a binary dependent variable, SYNDICATE, that equals 1 if a focal funding round receives funding from a syndicate, and 0 otherwise (as shown in equation (15a)). Furthermore, regarding the exclusion restriction, we follow Tian (2012) and include in the selection equation an instrument, IND_HHI, that measures industry concentration of investments by the lead VC firm since 2007 prior to a focal round.[36] The logic of the instrument is as follows: One of the motivations for VC syndication is for risk diversification (Lerner (1994) and Brander, Amit, and Antweiler (2002)). As a result, if a VC firm concentrates investments in a particular industry field, it will have an increased incentive to co-invest with other VC firms. Specifically, for the lead VC firm of a given round, we build their Herfindahl–Hirschman index to measure the dispersion of prior investments made in entrepreneurial firms in different industry groups. PitchBook reports the primary industry group that each entrepreneurial firm belongs to, and there are in total 41 different industry groups. IND_HHI ranges between 0 and 1, and a higher value indicates a higher degree of concentration in a VC firm's prior investments across different industry groups. In the selection equation, we also include the following controls: entrepreneurial firm centrality, logged age of entrepreneurial firm, development stage dummies, logged round investment size, industry group dummies of entrepreneurial firms, logged experience of lead VC firm, dummy indicating whether lead investor is government-backed, fixed effects for state locations of entrepreneurial firms, and fixed effects for investment years. In the second step of estimation as shown in equation (15b), we include the inverse-Mills ratio, λ_{evst}, generated from the first-step estimation. We perform such 2-step estimation by rounds of different sequence numbers.

[36]Our instrument strategy follows Tian (2012) in measuring industrywise concentration in the portfolio of a lead VC firm. However, our approach is not exactly the same as Tian's (2012). Due to data limitation, we are not able to precisely track the companies contained in the portfolio managed by a VC firm at a given time, and such information is necessary for the construction of Tian's (2012) style of instrument. Instead, we calculate HHI of industry concentration by considering all investments made by a focal lead VC firm since 2007 prior to a focal round.

The results from the 2-step Heckman estimation are presented in Table 6. Panel A reports the results from the second-step estimation. After controlling for the selection of syndication, we continue to find a significant and negative relationship between heterogeneity of VC experience in syndicates and entrepreneurial firms' network centrality for the first and second rounds (columns 1, 2, 5, and 6 in Panel A of Table 6). However, such negative relationships are not statistically significant for the third rounds, and in the fourth or later rounds, network centrality is positively and insignificantly related to the heterogeneity of VC experience levels in syndicates (columns 3, 4, 7, and 8 in Panel A of Table 6). Furthermore, the coefficients on the inverse Mills ratios show statistical significance in estimation using samples of the first rounds, highlighting the importance of adjusting for selection to obtain consistent estimates for those early rounds. Panel B of Table 6 reports coefficients from estimating the selection equation (15a). Consistent with our prediction, the industry concentration of lead VCs' prior investment portfolio positively affects the likelihoods of assembling a syndicate.

B. Switching and Heterogeneous Syndicates

Hypothesis 2 predicts that entrepreneurial firms are more likely to switch VC investors in follow-on funding rounds, when the VCs in the early-round syndicate have more heterogeneous experience levels. We test Hypothesis 2 by performing the following estimation:

$$(16)\quad \text{ALL\_SWITCH}_{evst} = \mathbf{1}\left[\alpha + \beta_1 \text{HET(EXP)}_{evst} + \beta_2 C_{et} + \beta_3 X_{vt} + \phi_s + \tau_t + \varepsilon_{evst} \geq 0\right],$$

where e, v, s, and t index the entrepreneurial firm, VC syndicate, state location of the entrepreneurial firm, and year, respectively. The dependent variable, ALL_SWITCH$_{evst}$, as explained in Section III.C, is binary indicating if *none* of the investing VC firms in the focal round invest in *any* subsequent funding rounds received by the entrepreneurial firm. Our main variable of interest is the heterogeneity of VC experience levels as captured by HET(EXP)_{evst} in the equation, and we use two alternative heterogeneity measures, namely CV and GINI.

We include a variety of additional regressors that might have an impact on entrepreneurs' decision to switch investors. Specifically, C_{et} indicates a set of controls for entrepreneurial firms' characteristics, including estimated probability of having a good exit (EST_GOOD_EXIT_PROB) and industry group dummies. Cumming and Dai (2013) document the following "graduation" phenomenon by entrepreneurial firms across rounds: As more information is disclosed across rounds of funding about potentials of a venture, entrepreneurial firms with increased perceived probabilities to succeed are more likely to switch investors. To control for that, we estimate the probability of having a good exit outcome. Following the literature (Ewens et al. (2016), Ewens and Marx (2018)), we define a good exit as either an IPO or an acquisition with a known valuation that is at least 2 times of all the capital invested in the focal entrepreneurial firm. Following Cumming and Dai (2013), we construct EST_GOOD_EXIT_PROB as follows: We run a probit regression in which the dependent variable equals 1 if an entrepreneurial firm eventually has a good exit, and 0 otherwise. We consider investments taking place in a time window from 2010 to 2014, leaving at least

TABLE 6

Heckman 2-Step Procedure: Effects of Network Centrality on Heterogeneity of VC Syndicates

Table 6 reports results from 2-step Heckman regressions, using all syndicated rounds raised between 2010 and 2014. Analysis is carried out by rounds of different sequence numbers (i.e., first, second, third, fourth, and later rounds). Panel A presents results from second-step estimation using two alternative heterogeneity measures (i.e., CV and GINI). Panel B reports coefficients from estimating the selection equation that uses SYNDICATE as the dependent variable, as shown in equation (15a). Standard errors are given in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Effects of Network Centrality on Heterogeneity of VC Syndicates

	CV				GINI			
	First Round	Second Round	Third Round	Fourth and Later Rounds	First Round	Second Round	Third Round	Fourth and Later Rounds
	1	2	3	4	5	6	7	8
CLOSENESS_CENTRALITY	−5.361***	−5.814**	−0.215	0.455	−3.572***	−3.769*	−0.608	0.546
	(1.706)	(2.696)	(2.871)	(1.648)	(1.202)	(2.001)	(2.179)	(1.219)
log(COMPANY_AGE)	0.0193*	0.0188	0.0518**	0.0255	0.0136	0.0129	0.0382**	0.0156
	(0.01160)	(0.01520)	(0.02060)	(0.01560)	(0.00852)	(0.01130)	(0.01560)	(0.01150)
log(DEALSIZE)	−0.006350	−0.055700***	−0.021400	0.032700**	−0.000996	−0.036100**	−0.015900	0.018000*
	(0.00784)	(0.02070)	(0.02030)	(0.01420)	(0.00577)	(0.01530)	(0.01540)	(0.01050)
GVC_LEADER	0.109	0.186	0.0561	0.0811	0.0891	0.111	0.0406	0.0470
	(0.1130)	(0.1920)	(0.1250)	(0.0935)	(0.0824)	(0.1420)	(0.0942)	(0.0693)
log(NO_OF_VCS)	−0.3360***	−0.3090***	−0.2850***	−0.3330***	0.0123	0.0361***	0.0719***	0.0304***
	(0.02170)	(0.01670)	(0.02180)	(0.01480)	(0.00935)	(0.01240)	(0.01640)	(0.01100)
log(EXP_OF_LEAD_VC)	0.0425***	0.0260***	0.0170**	0.0290***	0.0347***	0.0198***	0.0125**	0.0201***
	(0.00453)	(0.00876)	(0.00783)	(0.00619)	(0.00334)	(0.00649)	(0.00592)	(0.00459)
SEED_STAGE	−0.2240**	−0.0748	0.0356	0.0859**	−0.1500**	−0.0628*	0.0157	0.0461
	(0.0975)	(0.0481)	(0.0406)	(0.0390)	(0.0708)	(0.0356)	(0.0307)	(0.0289)
EARLY_STAGE	−0.184000***	−0.043700	−0.000877	0.039900**	−0.121000**	−0.031000	−0.002370	0.018600
	(0.0697)	(0.0316)	(0.0223)	(0.0183)	(0.0506)	(0.0234)	(0.0169)	(0.0136)
λ	−0.3730**	−0.1480	−0.1190	0.0678	−0.2630**	−0.1160	−0.1110	0.0126
	(0.1760)	(0.1100)	(0.0959)	(0.0756)	(0.1280)	(0.0812)	(0.0723)	(0.0561)
Investment year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ENT firm state dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prob. $>\chi^2$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
No. of obs.	1,779	1,985	1,508	2,757	1,779	1,985	1,508	2,757

Panel B. First-Stage Results from Estimating Selection Equation

	SYNDICATE			
	First Round	Second Round	Third Round	Fourth and Later Rounds
	1	2	3	4
IND_HHI	0.278***	0.353***	0.507***	0.221*
	(0.103)	(0.123)	(0.155)	(0.119)
CLOSENESS_CENTRALITY	−2.863	11.430	16.570	−4.080
	(12.540)	(11.480)	(14.270)	(7.722)
log(COMPANY_AGE)	0.0118	−0.0714	−0.1640**	−0.1840***
	(0.0397)	(0.0533)	(0.0746)	(0.0614)
GVC_LEADER	0.0454	0.0749	0.2150	0.1380
	(0.329)	(0.515)	(0.388)	(0.327)
log(DEALSIZE)	0.188***	0.389***	0.468***	0.445***
	(0.0341)	(0.0362)	(0.0396)	(0.0258)
log(EXP_OF_LEAD_VC)	0.191***	0.176***	0.183***	0.187***
	(0.0134)	(0.0160)	(0.0192)	(0.0146)
SEED_STAGE	0.765***	0.605***	0.388***	0.464***
	(0.120)	(0.120)	(0.140)	(0.141)
EARLY_STAGE	0.454***	0.242**	0.103	0.122
	(0.1070)	(0.0971)	(0.0866)	(0.0744)
Investment year dummies	Yes	Yes	Yes	Yes
ENT firm state dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
No. of obs.	3,261	2,942	2,134	3,791

6 years until our data extraction date (i.e., Feb. 2021) to track the exit status of an entrepreneurial firm. We include independent variables that control for characteristics of entrepreneurial firms, VC syndicates, and rounds. Those controls entail the development stages of an entrepreneurial firm at the time of a funding round, dummies of company geographic states, dummies of company industry groups, number of investing VC firms in a round, COMPANY_AGE, and the investment size of a round. Consistent with Cumming and Dai (2013), all these independent variables are significantly correlated with the probability of good exits. We continue to calculate the predicted probability of having a good exit outcome for an entrepreneurial firm at the time of each funding round, and use it as a proxy for the perceived quality of an entrepreneurial firm.

X_{vt} refers to the characteristics of investing VC firms, including i) logged value of the maximum experience of VC firms in a syndicate, ii) logged value of the maximum size of investing funds in the focal round, iii) distance between VC firms and entrepreneurial firms, and iv) indicator of whether any VC firm in the syndicate is headquartered in foreign countries. The logic of including those controls is as follows: As suggested in Cumming and Dai (2013), VC firms' experience affects switching decision by entrepreneurs. Furthermore, in raising a subsequent round, an entrepreneurial firm's request for capital support may exceed the capability of the existing VC firms', and thus an entrepreneurial firm has an increased incentive to switch investors (Cumming and Dai (2013)). To capture such effect, we control for the maximum size of all the investing funds in the focal round.[37] In addition, previous research suggests that geographic proximity positively affects effectiveness of monitoring by VC firms on entrepreneurial firms (Bernstein, Giroud, and Townsend (2016), Cumming and Dai (2010)) and, thus, is likely to affect the likelihoods of switching. Therefore, we include two binary variables, DIS_TO_VC<50_MILES and DIS_TO_VC_50_100_MILES, indicating if the geographic distance between VC firms and an entrepreneurial firm is less than 50 miles or between 50 and 100 miles, respectively. As we are interested in tracking the switching by *all* investing VC firms, information asymmetry faced by each individual investing VC firm in a syndicate is likely to have an impact on their switching decision. We therefore assign a value of 1 to the dummy indicator if there is *at least one* of the investing VC firms located in a distance from the focal entrepreneurial firm that falls into the range of interests (i.e., less than 50 miles or between 50 and 100 miles). We also include a dummy indicating whether any of investing VC firms in a syndicate is headquartered in a foreign country.

Finally, we include fixed effects for geographic state locations of entrepreneurial firms, ϕ_s, and for investment year, τ_t. Standard errors are clustered at the state level of entrepreneurial firms.

We estimate equation (16) using a sample of syndicated rounds that also receive a subsequent funding round. Furthermore, we run analysis by rounds of different sequence numbers. Performing by-round estimation not only controls for idiosyncratic features that are relevant only for a given round stage, but also helps us closely examine whether switching patterns of heterogeneous syndicates change

[37] In the event that the size of a particular investing fund is undisclosed, we use the average size of all the funds raised by the same investing VC firm prior to the focal round.

TABLE 7

Effects of Heterogeneity of VC Syndicates on Switching

Table 7 reports average marginal effects from estimating equation (16) in Probit, using a sample of all the funding rounds raised between 2010 and 2014 that were backed by a syndicate and also followed by a subsequent round of funding. Analysis is carried out by rounds of different sequence numbers (i.e., first, second, third, fourth, and later rounds). The estimation results are presented by rounds of different sequence numbers. All standard errors are clustered at the state level of the entrepreneurial firm and are given in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	ALL_SWITCH							
	First Round	Second Round	Third Round	Fourth and Later Rounds	First Round	Second Round	Third Round	Fourth and Later Rounds
	1	2	3	4	5	6	7	8
CV	0.153***	0.134***	0.171***	0.214***				
	(0.0370)	(0.0241)	(0.0274)	(0.0252)				
GINI					0.236***	0.202***	0.227***	0.286***
					(0.0642)	(0.0370)	(0.0477)	(0.0387)
EST_GOOD_EXIT_PROB	0.2410	0.1180	0.3630**	0.3920***	0.1300	0.0575	0.3100**	0.3170***
	(0.2860)	(0.2210)	(0.1600)	(0.0719)	(0.2670)	(0.2350)	(0.1540)	(0.0672)
log(MAX_VC_EXP)	−0.0496***	−0.0334***	−0.0318***	−0.0347***	−0.0568***	−0.0404***	−0.0372***	−0.0436***
	(0.00554)	(0.00700)	(0.01060)	(0.00909)	(0.00679)	(0.00760)	(0.01080)	(0.00995)
DIS_TO_VC<50_MILES	0.00777	−0.05040***	−0.02360	−0.05290**	−0.00502	−0.06130***	−0.03440	−0.06740***
	(0.0297)	(0.0173)	(0.0321)	(0.0227)	(0.0298)	(0.0175)	(0.0327)	(0.0234)
DIS_TO_VC_50_100_MILES	−0.0239	0.0755**	−0.0205	−0.0688*	−0.0304	0.0675**	−0.0234	−0.0832**
	(0.0500)	(0.0355)	(0.0492)	(0.0384)	(0.0512)	(0.0334)	(0.0495)	(0.0390)
FOREIGN_HQ_VC	0.01790	0.01100	−0.05170***	0.00446	0.00155	−0.00436	−0.06830***	−0.01250
	(0.0226)	(0.0208)	(0.0137)	(0.0198)	(0.0240)	(0.0222)	(0.0149)	(0.0205)
log(MAX_FUND_SIZE)	−0.0399***	−0.0317***	−0.0178*	−0.0325***	−0.0377***	−0.0294***	−0.0163	−0.0306**
	(0.00605)	(0.00664)	(0.01060)	(0.01130)	(0.00641)	(0.00666)	(0.01110)	(0.01190)
Investment year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ENT firm state dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R^2	0.16	0.16	0.11	0.10	0.16	0.16	0.11	0.09
No. of obs.	874	1,133	862	1,578	874	1,133	862	1,578

by rounds. Table 7 presents average marginal effects derived from Probit estimation of equation (16). In line with Hypothesis 2, we find that the degree of experience heterogeneity within a syndicate consistently has a positive and significant effect on the likelihoods of switching in the next round, holding all other things constant. Such significant effects arise for rounds of all sequence numbers. In terms of economic significance, for entrepreneurial firms receiving funding from a syndicate in their first funding round, as CV increases by one standard deviation (0.38 for the first-round observations in the sample), the likelihoods for switching of all syndicating VC firms increase by 6%. The magnitude of such increase represents about 28% of the average switching rate for the first-round observations (i.e., 21%).

Our results are subject to potential bias due to the selection of the sample. Our dependent variable, ALL_SWITCH, is only observable if an entrepreneurial firm survives to a subsequent round of funding. Furthermore, as explained in Section IV.A, our main variable of interests, HET(EXP)_{evst}, is available only if an entrepreneurial firm receives funding from more than one VC firm. Hence, occurrences of switching investors, syndication, and survival may be affected by common unobservables. For example, certain characteristics of an entrepreneurial firm may lead to formation of syndication when they are seeking funding and, in the meantime, are associated with the probabilities for those entrepreneurial

firms to survive to a follow-on round and then to switch VC firms. When those characteristics are not observable to econometricians, potential bias will arise in our estimation results.

To address selection problems, we jointly estimate a system of equations that describe the occurrences of three events: i) whether a syndicate is formed for funding a focal round, ii) whether an entrepreneurial firm survives to receive a subsequent round after a focal funding round, and iii) conditional on survival, whether an entrepreneurial firm switches VC investors in subsequent funding rounds. Such system of equations is as follows:

$$\text{(17a)}\quad \text{ALL\_SWITCH}_{evst} = \mathbf{1}\left[\alpha + \beta_1 \text{HET(EXP)}_{evst} + \beta_2 C_{et} + \beta_3 X_{vt} + \phi_s + \tau_t + \varepsilon_{evst} \geq 0\right],$$

$$\text{(17b)}\quad \text{SYNDICATE}_{evst} = \mathbf{1}\left[\alpha + \gamma_1 \text{IND\_HHI}_{evst} + \gamma_2 C_{et} + \gamma_3 X_{vt} + \phi_s + \tau_t + \psi_{evst} \geq 0\right],$$

$$\text{(17c)}\quad \text{SURVIVAL}_{evst} = \mathbf{1}\left[\alpha + \eta_1 C_{et} + \eta_2 X_{vt} + \phi_s + \tau_t + \xi_{evst} \geq 0\right].$$

Note that equation (17a) is the same specification with our previous investigation regarding switching likelihoods as described in equation (16). In the meantime, equation (17b) shares specification with equation (15a) to control for selection due to receiving funding from a syndicate, and includes IND_HHI to satisfy exclusion restriction. To control for selection due to the survivorship of the entrepreneurial firm, we rely on equation (17c), in which the dependent variable, SURVIVAL, takes the values of 1 if an entrepreneurial firm survives to a follow-on round, and 0 otherwise. The independent variables in equation (17c) include logged deal investment size, logged company age, logged number of VC investors, logged experience of lead VC firm, dummy indicating whether lead investor is government-backed, entrepreneurial firm development stage dummies, entrepreneurial firm industry group dummies, fixed effects for entrepreneurial firm state locations, and fixed effects for the year of investments.

We simultaneously estimate a multiequation system of Probit models and allow for correlation of error terms of equations (i.e., ε, ψ, and ξ). We employ the maximum simulated likelihood method using the GHK simulator, and make use of the user-written command *cmp* in Stata (see Roodman (2011)). We report in Table 8 the average marginal effects from estimating equation (17a) for separate samples of rounds of different sequence numbers. After controlling for potential selection bias, we continue to find a positive effect from VC syndicate heterogeneity (i.e., CV and GINI) on the likelihoods of switching in the follow-on rounds. This relationship holds for rounds of different sequence numbers. However, compared with the Probit results as reported in Table 7, the effects from the two alternative heterogeneity measures are now of reduced magnitudes, suggesting an upward bias if we do not control for the selection. Taken as an example the results using the first-round observations, holding all other things constant, as CV increases by 1 standard deviation (0.38 for the first-round observations), the likelihoods for switching of all investing VC firms increase by 4% (column 1 of Table 8). The magnitude of such increase represents about 20% of the average switching rate for the first-round observations (i.e., 21%). The statistical tests of correlations of the error terms for the

TABLE 8

Effects of Heterogeneity of VC Syndicates on Switching (Selection Corrected)

Table 8 reports results from correcting for selection by jointly estimating equations (17a)–(17c) using the observations of rounds raised between 2010 and 2014. Analysis is carried out by rounds of different sequence numbers (i.e., first, second, third, fourth, and later rounds). In Panel A, average marginal effects on the likelihoods of switching VCs in the subsequent rounds are presented. Panel B reports coefficients from two other jointly estimated equations in the system that describe the formation of a syndicate and survival to a subsequent round, respectively. All standard errors are clustered at the entrepreneurial firm state level and are given in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	ALL_SWITCH							
	First Round	Second Round	Third Round	Fourth and Later Rounds	First Round	Second Round	Third Round	Fourth and Later Rounds
	1	2	3	4	5	6	7	8
CV	0.1100**	0.0927***	0.1550***	0.1590***				
	(0.0498)	(0.0240)	(0.0298)	(0.0305)				
GINI					0.200***	0.153***	0.204***	0.222***
					(0.0626)	(0.0444)	(0.0434)	(0.0486)
EST_GOOD_EXIT_PROB	0.1470	0.0157	0.1730	0.2200**	0.0656	0.0128	0.1100	0.1610**
	(0.2510)	(0.1500)	(0.1850)	(0.1090)	(0.2500)	(0.1540)	(0.1770)	(0.06470)
log(MAX_VC_EXP)	−0.0353***	−0.0217**	−0.0302**	−0.0286***	−0.0391***	−0.0275***	−0.0343**	−0.0357***
	(0.01230)	(0.00865)	(0.01340)	(0.00795)	(0.01420)	(0.01070)	(0.01400)	(0.00907)
DIS_TO_VC<50_MILES	0.00735	−0.03650**	−0.02300	−0.03940**	−0.00217	−0.05820***	−0.02780	−0.04350**
	(0.0225)	(0.0142)	(0.0311)	(0.0191)	(0.0277)	(0.0210)	(0.0295)	(0.0189)
DIS_TO_VC_50_100_MILES	−0.01800	0.07380*	−0.00846	−0.04930	−0.03400	0.06770**	−0.01030	−0.04420
	(0.0393)	(0.0383)	(0.0469)	(0.0333)	(0.0406)	(0.0334)	(0.0428)	(0.0372)
FOREIGN_HQ_VC	0.01670	0.01460	−0.03850***	0.00195	0.01360	0.00793	−0.04800***	−0.01750
	(0.0158)	(0.0181)	(0.0145)	(0.0137)	(0.0210)	(0.0216)	(0.0152)	(0.0172)
log(MAX_FUND_SIZE)	−0.0303***	−0.0234**	−0.0190**	−0.0258**	−0.0309***	−0.0260**	−0.0163*	−0.0262***
	(0.00921)	(0.00966)	(0.00912)	(0.01150)	(0.01120)	(0.01080)	(0.00870)	(0.00757)
Investment year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ENT firm state dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
atanh($\rho(\psi,\xi)$)	−0.006940	0.051500	0.012100	0.025800	−0.009500	0.053800	−0.000332	0.007330
	(0.0290)	(0.0514)	(0.0772)	(0.0492)	(0.0294)	(0.0495)	(0.0733)	(0.0496)
atanh($\rho(\psi,\varepsilon)$)	0.217	0.461	−0.366	−0.142	0.0264	0.445	−0.412	−0.141
	(0.511)	(0.333)	(0.460)	(0.226)	(0.430)	(0.347)	(0.411)	(0.214)
atanh($\rho(\xi,\varepsilon)$)	−0.05480	−0.13300	0.38300	0.57000*	0.44300	−0.00773	0.61900*	0.70900*
	(0.630)	(0.457)	(0.405)	(0.319)	(0.425)	(0.471)	(0.322)	(0.381)
Prob $>\chi^2$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
No. of obs.	874	1,133	862	1,578	874	1,133	862	1,578

three equations are presented in the bottom of Table 8. Selection bias is likely to arise in estimation using the third- or fourth- and later-round observations, as suggested by the significant correlations of $\rho(\xi,\varepsilon)$ (columns 4, 7, and 8).[38] Overall, the results are in support of Hypothesis 2: Heterogeneity of VC experience in a syndicate is positively associated with likelihoods of switching by all the VC firms in later rounds.

Consistent with Cumming and Dai (2013), we find a positive effect of estimated likelihood of success, EST_GOOD_EXIT_PROB, on switching. However, such positive effects are statistically significant only for estimation results using the observations of the fourth and later rounds (see columns 4 and 8 in Panel A of Table 8). Cumming and Dai (2013) suggest that entrepreneurial firms with upwardly revised quality are more likely to switch VC firms, as those entrepreneurial firms

[38] In Table A.IV in Appendix H of the Supplementary Material, we report the coefficient estimates of equations (17b) and (17c).

"graduate" to seek for funding from new VC firms who are likely of higher reputation than their existing investors. Our finding supports the existence of such "graduation" phenomenon. However, it appears that switching due to revised quality of entrepreneurial firms predominantly arises in later rounds of funding (i.e., the fourth and later funding rounds).

V. Conclusion

An entrepreneur who seeks early-round financing for his project faces a trade-off. In the early round, a syndicate of VCs with highest skill levels can make most attractive offers because it will interpret the information delivered by this investment round most accurately. In the follow-on round, however, the informational advantage the incumbent VC syndicate has over alternative VCs allows it to hold up the entrepreneur. A syndicate of VCs with highest skill levels would then capture the full value of the project.

We show that the early-round syndicate that is most attractive to the entrepreneur consists of VCs with most heterogeneous levels of skills. Early-round syndicate heterogeneity increases the willingness of alternative syndicates to finance the follow-on round. It reduces the holdup by the incumbent VC syndicate, increasing the likelihood of syndicate switching. The driving force behind this heterophily is as follows: The early-round syndicate only offers follow-on financing if all VCs have a positive assessment of the project profitability. The benefit of heterogeneity is that, for the same probability this occurs, the likelihood that all early-round incumbent VCs receive negative signals is smaller. Then, any nonparticipation of a more heterogeneous incumbent syndicate sends a weaker negative signal to alternative VCs than the nonparticipation of a homogeneous incumbent syndicate.

This theory of informational holdup by incumbent syndicates can rationalize the following empirical observations: i) The VC firms that compose a syndicate regularly have different levels of experience, and ii) from one round to another, switching of VC firms is rather frequent. We test and find empirical support for two more specific predictions that emerge from this theory: i) There is a negative relationship between the heterogeneity of VC experience levels in syndicates and the extent to which the founders of the VC-backed firm are professionally well connected, and ii) there is a positive relationship between the heterogeneity of VC experience levels in syndicates and the likelihood of complete switching of VC firms in the following investment round. Our empirical results are robust to correcting for selection bias.

Several alleys are worthwhile exploring in future research. One is to examine a similar setup and informational hold up, taking that all VCs have an equal level of skills, in which each VC can obtain a signal, but the precision of this signal is an increasing concave function of the private cost the VC is willing to incur. Then a VC who has a large claim on the project return would produce a precise signal. A VC with a smaller claim would produce a more noisy signal. We have seen that disparity in VC signal precision renders the negative signal of nonparticipation of the incumbent syndicate milder. We would then expect that the ex ante optimal provision of incentives consists of providing early-round VC syndicate members with unequal equity stakes. What is here a heterogeneity of VC types result

presented in the current article would become a heterogeneity of VC incentive contracts result.

A second alley is to examine whether informational holdups by incumbent financiers provide a role for angel investors. First, angel investors are less sophisticated and spend less resources on due diligence than VCs. They can, therefore, play the same role as VCs with lower skill level in an early-round syndicate. Second, later rounds involve much more substantial investments than early rounds, and angel investors have much more limited funds than VCs. So, typically, angel investors do not participate to later rounds (Hellmann and Thiele (2015)). This is helpful here: Given that angel investors are not expected to finance a follow-on round, their non-continued participation does not send a negative signal to outside financiers.

Appendix

1. *Game*

Denote v the set of available VCs. The sequence of events and at each stage is as follows:

Date 1:

1. The entrepreneur seeks financing from a syndicate $\boldsymbol{i} \equiv (i_1, \ldots, i_N) \in v^N$ of its choice.

2. $\boldsymbol{i}$ makes a perfectly competitive date-1 offer (D_1, I_1, R_1) or does not make an offer.

3. If $\boldsymbol{i}$ makes a date-1 offer, the entrepreneur accepts or rejects it. If the offer is accepted, γ is invested in the project. Otherwise, the project is not financed and the game ends.

4. The entrepreneur exerts effort bearing a private cost ε, or does not exert effort. If she does not exert effort, the project generates no return and the game ends.

Date 2:

5. Each VC i_n in syndicate $\boldsymbol{i}$ has access to information of transparency φ and receives a signal $s_{i_n} \in \{\bar{s}_{i_n}, \underline{s}_{i_n}\}$. Signal s_{i_n} is independent from signal s_{i_m}, where $n, m \in \{1, \ldots, N\}$ and $n \neq m$. All VCs in $\boldsymbol{i}$ share their signals and know whether the entrepreneur exerted effort or not.

The inside syndicate $\boldsymbol{i}$ makes a Stackelberg leader date-2 offer R_2 to the entrepreneur, or does not make an offer.

6. If $\boldsymbol{i}$ makes a date-2 offer, the entrepreneur accepts or rejects it. If the offer is accepted, $1 - \gamma$ is invested in the project.

7. If $\boldsymbol{i}$ does not make a date-2 offer, or the offer is rejected, the entrepreneur seeks financing from an outside syndicate $\boldsymbol{k} \equiv (k_1, \ldots, k_N) \in v^N \setminus \boldsymbol{i}$ of its choice, or does not seek financing. If she does not, the project is not financed and the game ends.

8. Each VC k_n in $\boldsymbol{k}$ has access to information of reduced-transparency $\varphi\theta$ and receives a signal $s_{k_n} \in \{\bar{s}_{k_n}, \underline{s}_{k_n}\}$. Signal s_{k_n} is independent from signal s_{k_m}, where $n, m \in \{1, \ldots, N\}$ and $n \neq m$. All VCs in $\boldsymbol{k}$ share their signals and know the date-1 contract R_1, that the inside syndicate $\boldsymbol{i}$ did not finance the follow-on round, and whether the entrepreneur exerted effort or not.

The outside syndicate $\boldsymbol{k}$ makes a perfectly competitive date-2 offer R_2, or does not make an offer.

9. If $\boldsymbol{k}$ makes a date-2 offer, the entrepreneur accepts or rejects it. If the offer is accepted, $1-\gamma$ is invested in the project. Otherwise, the project is not financed and the game ends.

Date 3: The project's quality, G or B, and associated return, ρ or 0, are realized.

2. Comparison of Data Coverage Between Thompson One and PitchBook

Number of distinct funding rounds raised by U.S. entrepreneurial firms covered by each data set for each year from 2007 to 2014. Only rounds with a disclosed investment amount are considered.

Years	2007	2008	2009	2010	2011	2012	2013	2014
Thompson One	4,244	4,325	2,907	3,304	3,553	4,078	4,333	4,397
PitchBook	3,338	3,648	3,148	3,817	4,916	6,258	7,711	8,929

Supplementary Material

To view supplementary material for this article, please visit http://doi.org/10.1017/S0022109023000297.

References

Azarmsa, E., and L. Cong. "Persuasion in Relationship Finance." *Journal of Financial Economics*, 138 (2020), 818–837.

Beauchamp, M. A. "An Improved Index of Centrality." *Behavioral Science*, 10 (1965), 161–163.

Bergemann, D., and U. Hege. "Venture Capital Financing, Moral Hazard, and Learning." *Journal of Banking and Finance*, 22 (1998), 703–735.

Bernstein, S.; X. Giroud; and R. R. Townsend. "The Impact of Venture Capital Monitoring." *Journal of Finance*, 71 (2016), 1591–1622.

Bonaventura, M.; V. Ciotti; P. Panzarasa; S. Liverani; L. Lacasa; and V. Latora. "Predicting Success in the Worldwide Start-Up Network." *Scientific Reports*, 10 (2020), 1–6.

Brander, J.; R. Amit; and W. Antweiler. "Venture-Capital Syndication: Improved Venture Selection vs. the Value-Added Hypothesis." *Journal of Economics & Management Strategy*, 11 (2002), 423–452.

Bubna, A.; S. R. Das; and N. Prabhala. "Venture Capital Communities." *Journal of Financial and Quantitative Analysis*, 55 (2020), 621–651.

Burton, M. D.; J. B. Sørensen; and C. M. Beckman. "7. Coming from Good Stock: Career Histories and New Venture Formation." In *Social Structure and Organizations Revisited*, M. Lounsbury and M. J. Ventresca, eds. Bingley, UK: Emerald Group Publishing Limited (2002), 229–262.

Casamatta, C., and C. Haritchabalet. "Experience, Screening and Syndication in Venture Capital Investments." *Journal of Financial Intermediation*, 16 (2007), 368–398.

Cestone, G.; J. Lerner; and L. White. "The Design of Syndicates in Venture Capital." Working Paper, Banco Bilbao Vizcaya Argentaria (BBVA) Foundation (2008).

Cornelli, F., and O. Yosha. "Stage Financing and the Role of Convertible Securities." *Review of Economic Studies*, 70 (2003), 1–32.

Cumming, D., and N. Dai. "Local Bias in Venture Capital Investments." *Journal of Empirical Finance*, 17 (2010), 362–380.

Cumming, D., and N. Dai. "Why Do Entrepreneurs Switch Lead Venture Capitalists?" *Entrepreneurship Theory and Practice*, 37 (2013), 999–1017.

Deltas, G. "The Small-Sample Bias of the Gini Coefficient: Results and Implications for Empirical Research." *Review of Economics and Statistics*, 85 (2003), 226–234.

Ewens, M.; A. Gorbenko; and A. Korteweg. "Venture Capital Contracts." *Journal of Financial Economics*, 143 (2022), 131–158.

Ewens, M., and M. Marx. "Founder Replacement and Startup Performance." *Review of Financial Studies*, 31 (2018), 1532–1565.

Ewens, M.; M. Rhodes-Kropf; and I. Strebulaev. "Insider Financing and Venture Capital Returns." Working Paper, Stanford University (2016).
Fluck, Z.; K. Garrison; and S. Myers. "Hand in Hand or Hand in Bind? A Theory of Later-Stage Syndication of Venture Capital Investments." NBER Working Paper No. 11624 (2009).
Freeman, L. C. "Centrality in Social Networks Conceptual Clarification." *Social Networks*, 1 (1978), 215–239.
Gompers, P. "Optimal Investment, Monitoring, and the Staging of Venture Capital." *Journal of Finance*, 50 (1995), 1461–1489.
Gompers, P.; J. Lerner; and D. Scharfstein. "Entrepreneurial Spawning: Public Corporations and the Genesis of New Ventures, 1986 to 1999." *Journal of Finance*, 60 (2005), 577–614.
Hellmann, T., and V. Thiele. "Friends or Foes? The Interrelationship Between Angel and Venture Capital Markets." *Journal of Financial Economics*, 115 (2015), 639–653.
Hochberg, Y.; L. Lindsey; and M. Westerfield. "Resource Accumulation Through Economic Ties: Evidence from Venture Capital." *Journal of Financial Economics*, 118 (2015), 245–267.
Hochberg, Y.; A. Ljungqvist; and Y. Lu. "Whom You Know Matters: Venture Capital Networks and Investment Performance." *Journal of Finance*, 62 (2007), 251–301.
Hochberg, Y.; A. Ljungqvist; and Y. Lu. "Networking as a Barrier to Entry and the Competitive Supply of Venture Capital." *Journal of Finance*, 65 (2010), 829–859.
Hong, S.; K. Serfes; and V. Thiele. "Competition in the Venture Capital Market and the Success of Startup Companies: Theory and Evidence." *Journal of Economics & Management Strategy*, 29 (2020), 741–791.
Hsu, D. "What Do Entrepreneurs Pay for Venture Capital Affiliation?" *Journal of Finance*, 59 (2004), 1805–1844.
Hsu, D. H. "Experienced Entrepreneurial Founders, Organizational Capital, and Venture Capital Funding." *Research Policy*, 36 (2007), 722–741.
Kaplan, S., and P. Strömberg. "Financial Contracting Theory Meets the Real World: An Empirical Analysis of Venture Capital Contracts." *Review of Economic Studies*, 70 (2003), 281–315.
Kaplan, S., and P. Strömberg. "Characteristics, Contracts, and Auctions: Evidence from Venture Capitalist Analyses." *Journal of Finance*, 59 (2004), 2177–2210.
Katsnelson, J., and S. Kotz. "On the Upper Limits of Some Measures of Variability." *Archiv für Meteorologie, Geophysik und Bioklimatologie*, 8 (1957), 103–107.
Kerr, W.; R. Nanda; and M. Rhodes-Kropf. "Entrepreneurship as Experimentation." *Journal of Economic Perspectives*, 28 (2014), 25–48.
Kolympiris, C.; N. Kalaitzandonakes; and D. Miller. "Spatial Collocation and Venture Capital in the US Biotechnology Industry." *Research Policy*, 40 (2011), 1188–1199.
Landier, A. "Start-Up Financing: From Banks to Venture Capital." Working Paper, University of Chicago (2002).
Lerner, J. "The Syndication of Venture Capital Investments." *Financial Management*, 23 (1994), 16–27.
Mella-Barral, P. "Strategic Decertification in Venture Capital." *Journal of Corporate Finance*, 65 (2020), 101724.
Nahata, R. "Venture Capital Reputation and Investment Performance." *Journal of Financial Economics*, 90 (2008), 127–151.
Neher, D. "Staged Financing: An Agency Perspective." *Review of Economic Studies*, 66 (1999), 255–274.
Noldeke, G., and K. Schmidt. "Sequential Investments and Options to Own." *RAND Journal of Economics*, 29 (1998), 633–653.
PitchBook Data. "The In-Crowd: Does Lead Investor Status Affect Valuations and Returns?" PitchBook Q4 2020 Analyst Note (2020).
Rajan, R. "Insiders and Outsiders: The Choice Between Informed and Arm's Length Debt." *Journal of Finance*, 47 (1992), 1367–1400.
Repullo, R., and J. Suarez. "Venture Capital Finance: A Security Design Approach." *Review of Finance*, 8 (2004), 75–108.
Roodman, D. "Fitting Fully Observed Recursive Mixed-Process Models with cmp." *Stata Journal*, 11 (2011), 159–206.
Shane, S., and T. Stuart. "Organizational Endowments and the Performance of University Start-Ups." *Management Science*, 48 (2002), 154–170.
Sharpe, S. "Assymetric Information, Bank Lending and Emplicit Contracts: A Stylized Model of Customer Relationships." *Journal of Finance*, 45 (1990), 1069–1087.
Sitkin, S. B. "Learning Through Failure: The Strategy of Small Losses." *Research in Organizational Behavior*, 14 (1992), 231–266.
Sørensen, M. "How Smart Is Smart Money? A Two-Sided Matching Model of Venture Capital." *Journal of Finance*, 62 (2007), 2725–2762.

Stuart, T., and O. Sørensen. "The Geography of Opportunity: Spatial Heterogeneity in Founding Rates and the Performance of Biotechnology Firms." *Research Policy*, 32 (2003), 229–253.
Stuart, T. E.; H. Hoang; and R. C. Hybels. "Interorganizational Endorsements and the Performance of Entrepreneurial Ventures." *Administrative Science Quarterly*, 44 (1999), 315–349.
Tian, X. "The Role of Venture Capital Syndication in Value Creation for Entrepreneurial Firms." *Review of Finance*, 16 (2012), 245–283.
Uzzi, B. "Embeddedness in the Making of Financial Capital: How Social Relations and Networks Benefit Firms Seeking Financing." *American Sociological Review*, 64 (1999), 481–505.
von Thadden, E. "Asymmetric Information, Bank Lending and Implicit Contracts: The Winner's Curse." *Finance Research Letters*, 1 (2004), 11–23.
Wasserman, S., and K. Faust. *Social Network Analysis: Methods and Applications*. Cambridge, UK: Cambridge University Press (1994).
Yung, C. "Entrepreneurial Manipulation with Staged Financing." *Journal of Banking and Finance*, 100 (2019), 273–282.