Peer Monitoring, Syndication, and the Dynamics of Venture Capital Interactions: Theory and Evidence

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Abstract

We develop a theoretical model providing a new rationale for venture capital (VC) syndicate formation and empirically test our model predictions. An entrepreneur obtains financing and two different value-adding inputs from a single VC or from two different VCs, each operating in his area of expertise. We characterize the entrepreneur's equilibrium choice between contracting with: a single VC; individually with multiple VCs; or with a VC syndicate. We show that syndicates mitigate VCs' moral hazard problem in value addition. We also analyze the dynamics of VC syndicate composition. The results of our empirical analysis are consistent with our model's predictions.

I. Introduction

Syndicates are an important aspect of many economic activities. Starting from the seminal papers of Wilson (1968), who focused on the risk-sharing functions of a syndicate, and Alchian and Demsetz (1972) and Holmstrom (1982), who focused on moral hazard in production by teams (syndicates), there has been some very important analyses of syndicates in the context of the product market. However, there has been only a very small number of theoretical analyses of syndicates of venture capitalists (VCs), and no analyses of the evolution of VC syndicates and VC syndicate composition over time (i.e., on the dynamics of VC syndicates). The objective of this paper is to fill this gap in the literature by developing a new rationale for the formation of VC syndicates, and to analyze the dynamics of VC syndicates (theoretically and empirically) for the first time in the literature.

We address several interesting research questions in this paper. First, why do venture capitalists syndicate their investments in entrepreneurial firms? Second, what are the characteristics of projects that are financed through a VC syndicate relative to those that are financed by a single VC? It is worth noting here that, contrary to popular belief, while the financing of many entrepreneurial firms is indeed syndicated, many others obtain financing from a single VC (throughout their life or at least over some financing rounds). Third, even if the amount required to finance a project is so large that a single VC firm does not want to provide it by itself (for example, due to risk sharing considerations), why doesn't the entrepreneur strike separate contracts with different individual VCs rather than obtain the required financing from a VC syndicate? Fourth, what determines the dynamics of the structure of VC financing and the dynamic composition of VC syndicates? Many projects are financed by a syndicate in earlier rounds, but are financed by a single VC in later rounds, raising questions regarding the reasons underlying this change in the financing structure of the firm over time. Fifth, what will be the difference in performance between firms obtaining financing from a VC syndicate throughout all financing rounds and those that receive syndicate financing in earlier rounds but switch to single-VC financing in later rounds? Sixth, how does the performance of firms financed by syndicates consisting of the same set of VCs throughout various financing rounds differ from that of firms that are financed by VC syndicates whose membership changes across financing rounds (i.e., the relation between the dynamics of VC syndicate composition and entrepreneurial firm performance)? We first address the above research questions theoretically by developing a simple model of VC financing choice and then empirically test the predictions of our model.

Our theory rests on four important ingredients regarding the role of VCs in financing a firm's projects. First, VCs can add value (increase the probability of project success) to a firm's project by exerting effort beyond that of providing capital alone. Second, each VC may specialize in adding value to different aspects of a project, so that, in many cases, there may be a cost advantage arising from obtaining the services of more than one VC, with each VC adding value to the entrepreneurial firm in its own area of specialization. Third, obtaining the services of more than one VC may lead to a free-rider problem in value addition: clearly, the entrepreneur, given his own lack of expertise in the areas where the VC is able to add value, is unable to monitor the provision of effort by VCs. The fourth and final ingredient of our model is the ability of VCs to monitor each other, and punish slackers by not including them in future rounds and by imposing a reputational cost on them (e.g., by giving them a lower equity stake in lucrative future investments). Our theoretical analysis enables us to characterize the situations under which syndicates are the efficient vehicle for VC financing, and those under which financing by a single VC is optimal. We are also able to analyze the dynamics of VC financing across financing rounds: i.e., the dynamics of the VC financing sequence for a project (choice of syndicate versus individual VC financing across financing rounds), and the dynamics of VC syndicate composition (i.e., how the identity of VCs constituting a VC syndicate changes, endogenously across financing rounds) and relate these dynamics to the probability of successful firm exit.

We consider a setting in which an entrepreneur needs financing from a VC to implement his firm's positive net present value (NPV) project. We assume that the total financing amount is provided over two financing rounds. In addition to financing, VCs may provide the firm with two inputs required by it (each in a different area of activity) by exerting effort, thus increasing the probability of project success. Each VC may exert high or low effort in providing the above inputs, and is endowed with a high or low marginal cost of exerting high (relative to low) effort. The firm may obtain the two inputs either from a single VC or from two different VCs. Given that VCs specialize in different areas, it would be costlier (in terms of effort cost) for a single VC to provide both inputs compared to the case where each VC operates in his own area of expertise. If the firm chooses to obtain the two inputs from two different VCs, it then also chooses between contracting with the two VCs as a syndicate or with each of the two VCs individually. We assume that the effort exerted by a VC in providing the above inputs is unobservable to the entrepreneur but observable to the other VCs who may form part of a syndicate with him.[1]

[1] This assumption is made only for analytical tractability. In practice, the entrepreneur may observe some aspect of the effort provided by the VC to add value to the firm. All we require for our results to go through qualitatively is that co-investing VCs are able to obtain some additional information about the effort exerted by each VC over and above that observed by the entrepreneur.

If any one of the VCs in the syndicate shirks by providing low effort, the other VC observing this shirking can provide sufficient evidence to convince the entrepreneur that the VC is shirking and consequently not invite him for follow-on investment in the firm in the next round.[2] Meanwhile, the shirking VC will incur a reputation loss among his peers as well. In this case, the remaining VC can decide whether to invite a third VC to join in the syndicate or to invest alone in the following round. On the other hand, if the entrepreneur contracts with two VCs individually, the VCs cannot observe each other's effort. In this latter scenario, if any one VC provides low effort, he can continue to provide investments in the second round and will not be punished by incurring any reputation loss.

In the above setting, we analyze the equilibrium choice of an entrepreneur between financing the project by contracting with a single VC, by contracting individually with two VCs, or by contracting with a syndicate consisting of two VCs. We first discuss the two polar cases: first, where a VC finances the project alone in both rounds, and second, where two VCs finance the project but contract with the entrepreneur individually in both rounds.[3] We then discuss the

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[2] This is a simplification introduced for tractability. In practice, a VC observing another VC shirking may bring it to the notice of the lead VC in the syndicate who may exclude the shirking VC from future financing rounds. We abstract away from this in our formal model since we wish to keep the model simple by assuming that the VCs involved in a syndicate are symmetric to each other, so that there is no lead VC in our model.

[3] In the first case, the VC will always provide high effort in equilibrium, regardless of his effort cost. This is because there is no coordination (or free-rider) problem here and the VC is able to internalize the benefits of providing higher effort if his cost of providing the input outside his area of expertise is not too large. In the second (individual contracting with two VCs) case, both VCs will always provide low effort in equilibrium, regardless of their effort cost. In this case, the free rider problem among VCs is most severe, since each VC is unable to observe the other

case in which a syndicate consisting of two VCs finances the project in at least one round.[4] Comparing the three contracting alternatives available between entrepreneurs and VCs, we then show that contracting with two VCs individually is always a dominated strategy. Depending on project characteristics, it is either dominated by the strategy of contracting with a VC syndicate consisting of two VCs or by the strategy of obtaining financing from a single VC.

We then characterize the equilibrium choice of the number of VCs to finance the project and the contracting structure across the two financing rounds. The following tradeoff determines the equilibrium choice of the number of VCs financing the project. On the one hand, two VCs financing the project under a syndicate structure reduces the cost of providing high effort, since each VC provides the input lying within his own area of expertise. Such a benefit is especially significant if the project turns out to be very complex at each stage of its life. On the other hand, two VCs financing the project incurs a free-rider problem, which, although mitigated by the syndicate structure, continues to exist, leading to VCs with a high marginal cost of effort

VC's effort, so that there are no penalties for shirking, resulting in the equilibrium strategy for each VC being low effort provision.

[4] In this case, the VC faces the following tradeoff when deciding whether to provide high or low effort. On the one hand, the benefits of providing high effort are threefold: first, it increases the VC's expected payoff by increasing the probability of project success; second, it allows the VC to continue financing the project in the second round and thus enjoy a higher return on his investment (compared to the return from his alternative investment opportunity) in that round; third, it prevents the VC from incurring a reputation loss in the VC community that may affect his ability to co-invest with other VCs in the future (since his effort level can be observed by the other VC in the syndicate). On the other hand, the incremental cost of providing high effort may be large (recall that we assume that this incremental cost is different across VCs). If the above benefit of providing high effort dominates the cost of doing so, the VC exerts high effort; otherwise he provides low effort.

providing only low effort in equilibrium. If the above advantage of a syndicate consisting of two VCs financing the project dominates the disadvantage of doing so, a syndicate will be chosen to finance the project in equilibrium; otherwise a single VC will finance the project. We show that, depending on how project complexity evolves across financing rounds and the VCs' effort costs, the project may be funded by a single VC in both rounds; a syndicate consisting of two VCs in both rounds; a VC syndicate in its first round and a single VC in the second round; or the project may start with a single VC financing it in its first round, and be financed by a VC syndicate in the second round.

Our theoretical analysis generates several testable predictions. First, firms with projects in industries using more complex technologies are more likely to be financed by a VC syndicate. Second, while VC syndicate members are more likely to have expertise in a certain area of value addition to the entrepreneurial firm, VCs investing alone are more likely to be generalists who have some degree of expertise in multiple areas of value addition. Third, a given firm contracting individually (i.e., separately) with multiple VCs simultaneously (or over a short period of time) will rarely (if ever) be observed in practice. Finally, firms financed by a syndicate consisting of the same set of VCs throughout various financing rounds are more likely to have a successful exit compared to those that are financed by VC syndicates whose membership changes across financing rounds.

We test the above four predictions of our model using a sample of 11,880 entrepreneurial firms from the Thomson Venture Economics database. Our empirical findings may be summarized as follows. First, VCs are more likely to form syndicates when they invest in firms that are in more complex industries. Second, while specialist VCs are more likely to join in a VC syndicate to finance an entrepreneurial firm, generalist VCs are more likely to invest in the firm alone. Third, a given firm contracting separately with different VCs over a short period of time (defined as one month in our empirical analysis) is very rarely observed in the data, suggesting that such separate contracting is indeed suboptimal. Fourth, firms financed by a syndicate consisting largely of the same set of VCs across various financing rounds (i.e., characterized by more uniform VC syndicate dynamics) are more likely to have a successful exit outcome. We address the concern that the composition of VC syndicates across financing rounds is endogenous (i.e., higher quality firms will have syndicates consisting more of the same set of VCs), making use of an instrumental variable (IV) approach. To instrument for VC syndicate composition, we use the Industry Concentration Index (ICI) first constructed by Kacperczyk, Sialm, and Zheng (2005) and modified by Tian (2011) to capture the industry concentration of a lead VC's portfolio. Our IV analysis demonstrates that the relation we documented earlier between the dynamics of VC syndicate composition and the probability of successful exit is causal.

The rest of the paper is organized as follows. In Section II, we relate our paper to the existing literature, and discuss its contribution relative to this literature. In Section III, we describe the setup of our model. In Section IV, we characterize the equilibrium of our model and develop various results. In Section V, we describe the implications of our model and develop testable hypotheses for our empirical analysis. In Section VI, we present our empirical tests and results. We conclude in Section VII. The proofs of all propositions as well as the critical values specified in various propositions are given in Appendix A. Proofs of lemmas 1 to 3 are presented in an Appendix B.

II. Relation to the Existing Literature and Contribution

Our paper contributes to three different strands of literature. The first literature is the theoretical literature on VC contracting and value addition by VCs. Three examples of the theoretical literature on VC contracting are Ravid and Spiegel (1997), who study the nature of contracts that emerge between outside investors (such as VCs) and firm insiders in a setting characterized by moral hazard, Casamatta (2003), who analyzes the joint provision of effort by an entrepreneur and by a VC in a setting of double-sided moral hazard, and Chemmanur and Chen (2014), who study firms' choice between angel and VC financing and the dynamics of private firm financing contracts in a setting where both VCs and entrepreneurs may exert effort to create value for the firm.[5]

The second literature our paper is related to is the theoretical literature on VC syndication. A traditional explanation for VC syndication is the "diversification" hypothesis, which argues that syndication is simply a means of reducing the risk of VCs' portfolios through a standard diversification strategy: see, e.g., Lockett and Wright (1999). Another well-known hypothesis is the "second opinion" hypothesis, which argues that syndication is a mechanism through which a VC obtains a credible second opinion regarding whether the entrepreneurs' project is worth investing in. A recent theoretical paper examining this hypothesis is Casamatta and Haritchabalet (2007), who argue that when forming syndicates, VCs trade off the benefits of a second opinion against the costs of learning; Cestone, Lerner, and White (2006) extend this line of inquiry further by focusing on the question of "who syndicates with whom." Our paper contributes to this literature by developing a new rationale for VC syndication and by analyzing the dynamics of VC syndicates for the first time in the literature.

[5] Our paper is also distantly related to the literature on public versus private financing: see, e.g., Spiegel and Tookes (2007) or Chemmanur and Fulghieri (1999).

The third literature our paper is related to is the broader theoretical and empirical literature on syndicate and alliance formation and the theory of production in teams. In addition to the literature discussed earlier on the theory of syndicates, a more recent paper is Pichler and Willhelm (2001), who develop a theoretical model of investment banking syndicates in which syndicate members face a moral hazard problem in information production. In an important paper, Palia, Ravid, and Reisel (2008) analyze a firm's choice of financing a project internally versus financing it through outside alliances in the movie industry. They show that firms (movie studios) finance and develop safer projects internally while financing riskier projects through outside alliances. Robinson (2008) develops a theoretical model to explain why firms sometimes prefer alliances over internally organized projects and provides some evidence. Our paper contributes to this broader literature by suggesting a new rationale for the formation of syndicates and by providing a rationale for changes in syndicate composition and syndicate structure across financing rounds.[6]

III. Model

A. The Inputs provided by the VCs and VC effort

The model has three dates: time 0, 1, and 2. There are two types of agents in the model: the entrepreneur and VC investors, all of whom are risk neutral. The entrepreneur is endowed with a non-divisible project, which needs both an initial financing of $2I$ to be infused at time 0 and a follow-on investment of $2I$ at time 1 as well as the VC's effort, e, in each round. We refer

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[6] Our paper is also distantly related to the theoretical literature on group lending under either adverse selection or moral hazard: see, e.g., Ghatak and Guinnane (1999), Aghion and Gollier (2000), Ghatak (2000), Laffont and N'Guessan (2000) or Laffont (2003).

to the first round (time 0 to time 1) as the "earlier stage" of a project, and the second round (time 1 to time 2) as the "later stage" of that project.

In addition to providing funding for the entrepreneur's project, we assume that the VC can provide various inputs to the firm (e.g., contacts in various areas of its business or technical activities) by exerting effort. One example of two different types of VCs adding different aspects of value to entrepreneurial firms is provided by Chemmanur, Hull, and Krishnan (2016). They show that, when international VCs invest in entrepreneurial firms in emerging markets, they syndicate with local VCs, with the international VC providing technical expertise, while the local VC provides local market knowledge and monitors the entrepreneur. A second example is provided by Chemmanur, Loutskina, and Tian (2014), where corporate and independent VCs invest in start-up firms together as a VC syndicate. Here, the corporate VCs may provide the start-up firm with technical knowledge obtained from their parent firm, while the independent VCs may provide more traditional monitoring and other value added services.

In the above spirit, we assume that there are two different areas of activity, A and B, in which VCs can provide inputs to the firm, thus increasing the success probability of the project. These areas may be, for example, hardware and software (for a computer firm); or marketing and human resources (for any firm). The firm can obtain the above two inputs either from a single VC or from two different VCs. However, given that VCs specialize in different activities, it would be costlier (in terms of effort cost) for a single VC to provide both inputs A and B to the firm compared to the case in which a VC specializing in activity A provides input A and a VC specializing in activity B provides input B, as we formalize below.

In both rounds, we assume that the VC can provide one of two levels of effort: high (H) or low (L). For simplicity, we normalize the low level of effort to be zero ($L = 0$). If the high level of effort is exerted, it can increase the project's probability of success relative to the case in which a low level of effort is exerted. The cost of effort is $C > 0$ if the VC exerts high effort and 0 if the VC exerts low effort. There are two types of VCs: a type H VC has a high cost of exerting a high level of effort, i.e., $C(e = H) = C_H$; a type L VC has a low cost of exerting a high level of effort, i.e., $C(e = H) = C_L$, where $C_L < C_H$. VCs do not know their own type before the investment and realize it only after making the initial investment at time 0.[7] If a new VC is invited to provide funding at time 1, he will also realize his own type only after making the investment. Denote by q_i the prior belief that the VC$_i$ is of type L, i.e., $q_i = prob(C = C_L)$.

At time 2, the project's cash flow is realized to be 2R if the project succeeds and 0 if it fails. We assume that the payoff (realized cash flow) from the firm's project is shared between the VCs financing the firm and the entrepreneur, with the VCs receiving a fraction δ of the project's cash flow (each VC receives a fraction $\delta/2$ in case there are two VCs jointly financing the firm). The entrepreneur receives the remaining fraction $(1 - \delta)$ of firm cash flow. The fraction δ can be thought as emerging from Nash bargaining between the entrepreneur and the VC(s) initially financing the firm, and will depend, among other things, on the scarcity of VC financing in the economy. It is well known (from Nash bargaining theory) that as long as both the VCs' inputs and the entrepreneur's contribution to the project are needed for the project's

[7] Although VCs have expertise in financing projects, they still may not exactly know how hard the work is going to be in providing inputs for a particular project before they start doing the job. Thus, there may be project-specific aspects as well as VC-specific aspects in determining whether a VC is of the high-cost or the low-cost type in terms of adding value to a given project. Our results go through even if VCs have some private information about their own type (cost of exerting high effort): we only require that VCs have some additional project-specific uncertainty about this cost which is resolved only when they start working on the project.

success, any sharing rule ($0 < \delta < 1$) of the firm's cash flow can be supported as a solution to the Nash bargaining game between the entrepreneur and the VCs. Thus, while the solution to the Nash bargaining game itself does not impose any strong restrictions on δ, additional restrictions on δ will emerge naturally (depending on the economic setting) as we proceed with our analysis. We will discuss these restrictions (and the intuition behind them) below in the order in which they arise.[8]

We assume that $\delta R > 2I + 2C_H$, i.e., financing the project is positive NPV to the VC regardless of the type of VC investing in the project. We assume that the VC's opportunity cost of investing in the project is the risk-free rate, and for simplicity, we normalize the risk-free rate of return to be zero. The sequence of events is depicted in Figure 1.

[Insert Figure 1 about here.]

The incremental cost of high effort over low effort will be *C* only when a VC provides an input in his specialized area of activity, where $C \in \{C_L, C_H\}$ depending on VC type. Thus, we assume that, if a VC specializing in activity *A* provides input *A* to the firm and a VC specializing in activity *B* provides input *B* to the firm, and each VC exerts high effort, the aggregate cost will be $2C_L, 2C_H$, or $(C_L + C_H)$, depending on the type of the VC providing each input at each round of the project.

If, however, a single VC provides both inputs to the firm in each round, then the aggregate cost of providing high effort will be $k_j C,\ C \in \{C_L, C_H\},\ j = 1, 2$, where $k_j > 2$. The

[8] Our assumption here is that the cash flow from the firm's project is fully contractible (i.e., δ and $(1 - \delta)$ are contracted upon in advance). Note that, as long as the entrepreneur receives a positive fraction of the project cash flow, the precise sharing rule of this cash flow between the entrepreneur and the venture capitalist does not drive any of our results.

parameter k_j measures the extent to which a single VC must incur greater effort costs to provide both of the required inputs *A* and *B* (over and above the total cost $2C$ that two VCs, each specialized in its own area of input provision, need to incur to provide the same two inputs) in the j^{th} financing round ($j = 1, 2$; corresponding to financing rounds 1 and 2 respectively). This parameter can be viewed as a measure of the complexity of the project (in round j) in the sense that it measures how different the two inputs that the project requires from the VCs are from each other. Thus, if the project is complex, so that the two inputs are quite different from each other, it will be very costly for any one VC to provide both inputs to the firm, and k_j will be significantly greater than 2. If, however, the project is relatively simple, so that the two inputs are closely related to each other, k_j will only be slightly greater than 2, since, in this case, both inputs can be provided at a relatively low cost by a single VC (although the aggregate effort cost in this case will nevertheless be greater than the aggregate effort cost where a VC specializing in activity *A* provides input *A*, and a VC specializing in activity *B* provides input *B*). One should also note that we allow for the complexity of the project to change over financing rounds as well, so that k_1 may be different from k_2 for a given project.

Throughout the paper, we abstract away from any effort that the entrepreneur needs to exert to make his firm's project a success. However, in practice, the entrepreneur may need to provide effort and other valuable inputs (see, e.g., Casamatta (2003) or Chemmanur and Chen (2014)) to facilitate project success and may also contribute part of the financing required for his firm's project (see, e.g., Ravid and Spiegel (1997)), or both. However, even if we were to add entrepreneurial efforts or other inputs to our model (at the expense of making the model more complex), our results will remain qualitatively unchanged (both theoretically and empirically), as long as VCs need to provide two or more inputs in addition to the effort or other inputs provided by the entrepreneur. Therefore, since our focus in this paper is on the provision of inputs by VCs and the structure of contracting between the entrepreneur and VCs, we abstract away from the provision of effort or other inputs by the entrepreneur in the interest of modeling simplicity.

B. The Three Different Modes of VC Financing

At the time when the venture financing of the project is entered into, two choices need to be made. First, whether to obtain the venture financing and required inputs from a single VC, or from two different VCs. Second, if the financing is to be provided by two VCs, then the contracting arrangement between the entrepreneur and the two VCs needs to specify whether the firm will contract with the two VCs as a syndicate or with each VC individually. The choice between the above three modes of financing (single VC, two individual VCs, or VC syndicate) will emerge in equilibrium in our model. We assume that the entrepreneur proposes the project to a first VC (labeled as VC_1).[9] If VC_1 decides to finance the project, he chooses among the following three arrangements: to finance the project alone; to invite a second VC labeled as VC_2 to form a VC syndicate with him; or to suggest to the entrepreneur to contract with a second VC (VC_2) individually. We discuss each of these three arrangements in more detail below.

If VC_1 decides to finance the project alone, he has to provide the entire required investment of $2I$ in the first round. As discussed before, if he provides a high level of effort in both rounds and finances the project by himself (alone), his aggregate cost of effort will be $k_j C_i, C_i \in \{C_H, C_L\},\ j = 1, 2,$ in round 1 and round 2, respectively.

In the case where VC_1 decides to invite VC_2 to form a syndicate, we assume that the VCs within a syndicate are able to observe each other's effort, and each VC provides an amount

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[9] In practice, the first VC the firm approaches may become the lead VC if a syndicate financing structure is chosen as the equilibrium arrangement. We abstract away from modeling a lead VC for simplicity of modeling.

I for investment in the first round. If a VC exerts high effort in the first round, then he will continue to finance the project in the second round by investing the required second-round capital infusion of I at time 1. In the case where any VC shirks by providing low effort in the first round, the other VC in the syndicate may provide sufficient evidence of that VC's shirking to convince the entrepreneur that the VC is shirking and consequently not invite him for follow-on investment in the firm in the next round.[10] Further, the shirking VC will incur a reputation loss, denoted by B.[11] We denote the VC who provides a high level of effort in the first round as VC_1 and the shirking VC as VC_2 when only one VC shirks. The model goes through if we reverse the notation since the two VCs are symmetric. If VC_2 shirks, then VC_1 may decide either to finance the project alone in the second round or invite a third VC, labeled VC_3, to invest in the

[10] This is a natural assumption, given the repeated interactions between venture capitalists across projects. It is in the interest of each venture capitalist to co-syndicate with other VCs that are diligent at value-addition into entrepreneurial firms, so that this is a dynamically consistent (subgame-perfect) strategy for each VC. In practice, the decision to not invite a VC into the syndicate for a follow-on round may be made by the lead VC of the syndicate rather than by the entrepreneur. While we abstract away from the role of the lead VC for tractability purposes, this does not drive any of our results.

[11] We have adopted the simplest way of modeling reputation loss here: see Chemmanur and Fulghieri (1994a) and Chemmanur and Fulghieri (1994b) for a more elaborate way of modeling reputation in the setting of investment banking and commercial banking, respectively. There is also some evidence of VCs losing reputation due to bad project outcomes in practice. Atanasov, Ivanov, and Litvak (2012) find that VC investors' reputation is substantially hurt if they get involved in litigation as defendants (i.e., sued by other VCs or the entrepreneurs). Specifically, they find that VCs involved in litigation as defendants syndicate with fewer VC firms subsequently. Tian, Udell, and Yu (2016) show that VCs experience reputation losses and are punished by their peer VCs and other financial market players, such as their limited partners and investment banks, if they are discovered as inefficient monitors when their previous IPO firms are found to commit accounting fraud before going public.

second round. Similar to the first round, in the second round also, VC_1 and VC_3 are able to observe each other's effort within the syndicate, and any shirking VC will incur a reputation loss *B*. Alternatively, both VCs may shirk in the first round. If both VCs shirk in the first round, the project fails and will be liquidated and both VCs will incur the reputation loss *B*.[12] In our model, the investment amount (I per each VC if there are two VCs or $2I$ if there is only one VC) in a VC financing round also matters significantly, because the fraction of total cash flows ($2R$) that the VC receives (in case the firm's project is successful) is proportional to the total amount invested by the VC over the two financing rounds. Therefore, the investment amount (a multiple of I) affects the VCs' expected payoffs when they decide whether they should exert effort in a financing round or not.

We assume that, while each VC is able to observe the effort exerted by the other VC (in the case of VC syndication), and can communicate this credibly to the entrepreneur (who cannot observe this effort directly), the effort exerted by a VC is not verifiable, i.e., it cannot be proved in court that a VC exerted low effort, so that effort cannot be contracted upon. This assumption that effort is observable but not contractible is standard in the incomplete contracting literature

[12] One may conjecture that our results will go through even when the reputation cost *B* of shirking is zero, since a VC caught shirking in the first round will not be allowed to participate in the project's second round investment syndicate (and the VC's rate of return from investing in the project is greater than those from his alternative investment opportunity). This, however, is not the case, since, in the absence of such a reputation cost, the VCs participating in the project's second round investment syndicate do not have any disincentive that will prevent them from shirking. Thus, assuming a reputation cost *B* to VCs who shirk allows us to capture the effects of the infinite-horizon setting that VCs work with in practice (while using a finite-period model for analytical simplicity). In other words, one can think of the reputation cost *B* as the present value of the loss in a VC's profits from all future periods if it were to be known in the VC community that he had shirked in a prior period.

(see, e.g., Grossman and Hart (1986), Hart and Moore (1990), or Aghion and Bolton (1992)). Thus, the cost to a VC from shirking arises from the fact that he will not be invited to finance the second round of the project (so that he has to earn a lower rate of return on the funding amount I from his alternative investment opportunity as well as incur the reputation cost B). It can also be shown that a VC does not have an incentive to falsely report to the entrepreneur that a co-investing VC has shirked in either period (recall that all VCs are symmetric in our setting, so that a VC shirking in the first round will be replaced by another VC).

When the entrepreneur contracts with two VCs individually, each VC provides an investment I and effort e, $e = H$ or $e = L$, individually to the firm in each round. Unlike in the case of VC syndication, in this case, VCs are not able to observe each other's effort. Therefore, if any one VC shirks, he will not incur a reputation loss B. Meanwhile, if one VC shirks in the first round, he will continue to provide investment I for the second round since his effort is not observable by anyone other than himself, while in the case of VC syndication he will not be invited to provide the follow-on investment if he shirks in the first round. We will demonstrate later that this mode of financing (contracting with two different VCs individually) will never be chosen by firms in equilibrium: i.e., it is a strategy dominated by one of the two alternatives discussed earlier.

C. The Relationship between VC Financing Sequence, VC Effort, and Probability of Project Success

The project's probability of success, denoted by $P(\cdot)$, depends on the financing choices made by the entrepreneur as well as the VC's effort choice in each round. There are four possible VC financing sequences: two VCs finance the project in each round (*Sequence 1*); two VCs finance the project in the first round and one VC finances the project alone in the second round if the other VC shirks in the first round (*Sequence 2*); a single VC finances the project in the first round and two VCs finance the project in the second round (*Sequence 3*); and finally a single VC finances the project alone in both rounds (*Sequence 4*). Note that the contracting choice made by the entrepreneur in the two VC financing case (i.e., the choice between VC syndication versus contracting individually with two VCs) affects the probability of project success only through its effect on the effort exerted by VCs.

Sequence 1: We assume that, if two VCs finance the project in both rounds, the probability of project success, $P(e_{12},e_{22} \mid e_{11},e_{21})$, evolves as follows, depending on the effort exerted by VC_1 and VC_2 in the first round and the second round respectively:

(1) $P(H,H|H,H) = 1;\ P(H,L|H,H) = P_H;\ P(L,L|H,H) = P_L,$

(2) $P(H,H|H,L) = P_M;\ P(H,L|H,L) = P_L;\ P(L,L|H,L) = 0,$

(3) $P(H,H|L,L) = P(H,L|L,L) = P(L,L|L,L) = 0,$

where $1 > P_H > P_M > P_L > 0$ and e_{ij} refers to the effort level of VC_i in period j. In other words, if both VCs in the syndicate provide high effort in both rounds, the project will succeed with probability 1. If both VCs provide high effort in the first round, but one VC shirks in the second round, the project will succeed with probability P_H. Conversely, if one VC shirks in the first round and both VCs in the syndicate exert high effort in the second round, then the project's probability of success drops down to P_M. The assumption $P_H > P_M$ implies that, consistent with practice, VC effort is more important in the first round than in the second round. If both VCs provide high effort in the first round but both VCs shirk in the second round, or if one VC shirks in the first round and one VC shirks in the second round, the project will succeed with probability P_L. However, if both VCs shirk in the first round, the project's probability of success will be zero regardless of VC effort levels in the second round. Our assumption that $P_L > 0$, once again, captures the notion that VC effort is more important in the first round relative to the second round. Finally, our assumption that $P_H < 1$ and $P_M > P_L$ reflect the idea that the effort level of both VCs are important in determining the probability of project success.

Sequence 2: This sequence considers the case where two VCs finance the project in the first round but VC_2 shirks, and VC_1 decides to finance the project alone in the second round (instead of inviting another VC to co-invest, as in sequence 1). The probability of project success then evolves as follows:

(4) $P(H|H,L) = P_M; P(L|H,L) = 0,$

(5) $P(H|L,L) = P(L|L,L) = 0,$

where $1 > P_M > 0$. Note that the assumptions we make on the success probability of the project in this sequence are consistent with the assumptions we are making in sequence 1. We assume that when a single VC is financing the project alone (either in round one or in round two) he will provide identical levels of effort with respect to both inputs.[13] Given this assumption, it should be clear that assumptions (2) and (4) are similar, with the difference that assumption (4) pertains to the case in which only one VC is providing inputs to the firm in the second round, while assumption (2) describes the success probability when two VCs are providing such inputs to the firm in the second round. Similarly, assumptions (3) and (5) are very similar, with the only difference being in the number of VCs providing inputs to the firm in the second round. In summary, these assumptions imply that even if VC_1 finances the project alone in the second

[13] For simplicity, we do not allow a VC financing the firm's project alone in a given period to provide high effort when providing one input and low effort when providing the other input. Doing so will not change the qualitative nature of our results; however, this will considerably complicate various expressions.

round, the project can reach the same probability of success as in sequence 1 if he provides high effort, with the difference that providing high effort will be more costly in sequence 2.[14]

Sequence 3: This sequence deals with the case where VC_1 finances the project alone in the first round and decides to invite another VC, VC_3, to co-invest in the second round. Then the success probability of the project evolves as follows:

(6) $P(H,H|H) = 1;\ P(H,L|H) = P_H;\ P(L,L|H) = P_L,$

(7) $P(H,H|L) = P(H,L|L) = P(L,L|L) = 0,$

where $1 > P_H > P_L > 0$. It is worth noting again that the assumptions we make regarding the project's success probability in sequence 3 are consistent with the assumptions we make in sequences 1 and 2. Thus, assumption (6) is very similar to (1), with the only difference being the number of VCs providing inputs to the firm in round one. Similarly, assumptions (7) and (3) are similar, with the only difference being in the number of VCs providing inputs in the first round. In summary, as long as VC_1 provides high effort in the first round, the evolution of the success probability will be the same as that in the case where both VCs provide high effort in sequence 1. If, however, VC_1 shirks in the first round, the project's probability of success will be zero regardless of the two VCs' effort levels in the second round (similar to the case when both VCs shirk in the first round in sequence 1).

Sequence 4: This sequence deals with the case where VC_1 finances the project alone in both rounds. The success probability of the project then evolves as follows:

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[14] As discussed before, since VC_1 does not have expertise in providing input in the specialization area of VC_2 and even though he can push the project's probability of success to the same level as a syndicate with effort level of (H, H) in the follow-on round, his cost of exerting high effort will be k_2C_i, which is greater than that if two VCs were providing inputs, each in its own area of specialization.

(8) $P(H|H) = 1; P(L|H) = P_L$,

(9) $P(H|L) = P(L|L) = 0$;

where $1 > P_L > 0$. It is worth noting here also that the assumptions we make regarding the success probability of the project is consistent with those in previous sequences. Thus, assumption (8) is similar to (1), with the only differences being the number of VCs providing inputs to the firm in each round. Similarly, assumption (9) is similar to (3), with the only difference being in the number of VCs providing inputs to the firm in each round. In summary, if VC_1 provides high effort in both rounds, he can push the project's probability of success to 1, while if he works hard in the first round but shirks in the second round, the project's success probability is reduced to P_L. Finally, if he shirks in the first round, the project succeeds with probability 0 regardless of his effort level in the second round.

Overall, the above assumptions are meant to capture the following ideas: first, provision of a high level of effort is important with regard to each input; second, provision of a high level of effort is more important in the first round compared to its importance in the second round in determining project success.

D. The Objectives of the VC and the Entrepreneur

The objective of the entrepreneur in choosing the number of VCs to finance his project and the mode of contracting (if there is more than one VC financing the firm) is to maximize his expected cash flows from his firm's project. This, in turn, depends on the effort provided by the VC(s) financing the firm's project in two rounds, which, in turn, is affected by the cost to the VC(s) of providing the above effort.[15] Given the choice of the number of VCs financing the firm

[15] While we have specified that the choice of the number of VCs financing the firm's project and the mode of contracting are chosen by the entrepreneur, our result will remain unchanged if the VC was to make the above

and the contracting mode chosen by the entrepreneur in each round, each VC decides whether or not to finance the firm on the terms offered by the entrepreneur, and if so, the amount of effort to exert in each round. Each VC makes the above choices in each period so as to maximize his expected future cash flows net of investment and effort costs.

IV. Equilibrium

We will now characterize the equilibrium of the model. Equilibrium strategies and beliefs in our model are defined as those constituting a Pareto-dominant (Efficient) Pure Strategy Perfect Bayesian Equilibrium (PBE) which survives the Cho-Kreps intuitive criterion. Before going on to characterize the equilibrium of our model, we analyze the problem faced by VCs under different contracting arrangements.[16] Below, we will first analyze the case where a VC finances the project alone in both rounds. Second, we will analyze the case in which a syndicate consisting of two VCs finances the project in at least one round. Third, we will analyze the case where two VCs finance the project but contract with the entrepreneur individually. Finally, we will discuss the equilibrium of the overall VC financing game.

A. Analysis of the Single VC Financing Case

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choices. This is because, since the entrepreneur and the venture capitalist receive a pre-specified fraction of the cash flows from the firm's project, it is in the interest of both parties to make the above choice so as to maximize these expected cash flows.

[16] Thus, we look for Perfect Bayesian Equilibria which maximize the objective of the entrepreneur and the VCs, by minimizing the dissipative costs incurred by them. See Fudenberg and Tirole (1991) for a formal definition of a PBE, and Milgrom and Roberts (1986) for an application of Pareto-dominant (Efficient) PBE to signaling games. The Cho-Kreps Intuitive Criterion is formally defined in Cho and Kreps (1987).

In this section, we study the case in which a single VC, VC_1, finances the project in both rounds. If VC_1 finances the project alone in both rounds, his payoff will be $(2\delta R - 4I - (k_1 + k_2)C_i)$ conditional on exerting a high level of effort in each round. If VC_1 shirks only in the second round, his payoff will be $(2P_L\delta R - 4I - k_1C_i)$. If he shirks in the first round, his payoff will be negative (recall that the payoff from the project is zero) regardless of his effort level in the second round.

Lemma 1 *Let* $2(1 - P_L)\delta R > k_2C_H$*. If a VC decides to finance a project alone in a given round, he will always provide high effort, regardless of type.*

In this case, there is no co-ordination (or free-rider) problem between VCs, since a single VC is able to internalize the benefits of providing high effort. If the parameter condition specified in Lemma 1 holds, the VC's incremental benefit $(2(1 - P_L)\delta R)$ from exerting effort in the second round is sufficiently large so that it exceeds his incremental effort cost (k_2C_H), even if his type is realized to be high-cost (type H). Thus, if a single VC chooses to finance the project alone, he will always choose to provide high effort rather than shirking (under the parameter values specified in Lemma 1). In summary, the advantage of a single-VC financing the project alone is that there is no free-rider problem as would exist if there is more than one VC financing the project. The disadvantage of a VC financing the project alone is that since the VC's expertise is only in one area, it is more costly for him to provide both inputs compared to the case where two VCs provide these inputs to the firm, each in his own area of expertise.

B. Analysis of the Two VC Syndication Case

In this section, we analyze the equilibrium strategies of VCs when the entrepreneur contracts with a VC syndicate in at least one round. We discuss the trade-offs faced by VCs in arriving at their equilibrium strategies in terms of effort provision when they form a syndicate to finance the project. In particular, we analyze how VCs arrive at their effort choices based on the financing sequence chosen by the entrepreneurial firm in equilibrium. Later, we will also analyze the equilibrium choice of syndication sequence in Section IV.D (where we discuss the overall equilibrium of the model).

Lemma 2 *Let* $C_L \leq C_L^*$ *and* $C_H > C_H^*$*, where the thresholds* C_L^* *and* C_H^* *are given in Appendix B.*

(i) If a VC syndicate finances the project in one or both of the rounds, there exists an equilibrium where, in each round, a VC provides a low level effort if he is a high-cost VC and a high level of effort if he is a low-cost VC.

(*ii*) *If a VC, namely* VC_2*, shirks in the first round, he is asked to leave the syndicate at the end of the first round. If a new VC, namely* VC_3*, with the same expertise as* VC_2 *is then invited to join the syndicate, he will follow the same effort provision strategy (depending on type) as* VC_1 *and* VC_2.

Part (i) of the above lemma characterizes VC effort choices in an equilibrium where a syndicate consisting of two VCs finances the project in one or both of the financing rounds (recall *Sequences* 1, 2, and 3 from Section III.C). If a VC's type is realized to be high-cost and the effort cost C_H of a high-cost VC is larger than the threshold value C_H^*, it is optimal for him to provide only a low level of effort in any syndicate-financing round. On the other hand, if a VC's type is realized to be low-cost and the effort cost C_L of a low-cost type VC is smaller than the threshold value C_L^*, it is optimal for him to provide a high level of effort in any syndicate-financing round.

Part (ii) of Lemma 2 characterizes the properties of the equilibrium in which a VC syndicate finances the firm in the first round (*Sequence* 1 or *Sequence* 2). If both VCs provide high effort in the first round (i.e., they are both low-cost types), they will find it optimal to finance the project in the second round as well. If one VC (VC_2) shirks in the first round, then he will not be invited to co-invest in the project in the second round, and he will incur a reputation loss B. In this case, in the second round, either the other VC (VC_1) will invite a new VC (VC_3), with the same expertise as VC_2, to join the syndicate or VC_1 will finance the project alone. If both VCs shirk in the first round, they know that the project will fail with probability 1 regardless of their effort levels in the second round, so that they will write off the project at the end of the first round.

The intuition behind the effort provision decision of each VC in a VC syndicate is as follows. The benefits of providing high effort to a VC arise from three sources: first, it increases the expected cash flow from the project (a fraction of which goes to the VC) by increasing the probability of project success; second, it allows the VC of a first-round syndicate to continue financing the project (recall that the shirking VC will not be invited back into the second-round syndicate and will therefore earn a lower rate of return on his funds from the alternative investment opportunity); third, a shirking VC will suffer a reputation loss B. If a VC's type is realized to be high-cost and his effort cost is sufficiently large (i.e., $C_H > C_H^*$), he chooses to provide only a low level of effort in any syndicate-financing round, since the incremental cost of providing high effort for a high-cost VC dominates the potential benefits of doing so. On the other hand, if a VC's type is realized to be low-cost, it is optimal for him to provide high effort in each syndicate-financing round, since, for such a VC with sufficiently low effort cost (i.e., $C_L \leq C_L^*$), the above described benefits of providing a high level of effort dominate the incremental cost of doing so. In other words, VC syndicate monitoring has a disciplining effect only on low-cost type VCs.

C. Analysis of the Suboptimal Case of Contracting with Two VCs Individually

If the entrepreneur contracts with two VCs individually, each VC is unable to observe the other's effort level. Consequently, if one VC provides low effort in the first round, he will not be found out and will continue to provide the investment *I* in the second round. Under this contracting structure, the shirking VC will not incur a reputation loss *B*, since his shirking will not be discovered by either the entrepreneur or the other VC.

Lemma 3 *Let* $C_L > \overline{C}_L \equiv \max((1 - P_H), (P_H - P_L), P_L)\, \delta R$. *If the entrepreneur contracts with two VCs individually, there exists an equilibrium that involves both VCs providing a low level of effort in both rounds, regardless of VC type.*

The above lemma characterizes the equilibrium in which both VCs will shirk in both rounds. The intuition here is that if each VC cannot observe the other VC's effort and there are no penalties for shirking, the dominant strategy for each VC in the second round is shirking (to save his cost of effort). Expecting the equilibrium strategy in the second round, the dominant strategy for each VC in the first round is to shirk as well. Consequently, the equilibrium strategy for each VC under the individual contracting arrangement is to provide a low level of effort in both rounds. Shirking is a dominant strategy for both types of VCs in this equilibrium, if the effort cost C_L for a low-cost type VC is greater than the threshold $\overline{C}_L$ given in the above lemma. Given this, we will later show in Proposition 2 that separate contracting with two VCs is a suboptimal choice for the entrepreneur in the overall equilibrium.

D. Overall Equilibrium

In this section, we analyze the entrepreneur's choice of the number of VCs to finance the project, as well as his choice of contracting structure (syndicate formation versus individual contracting).[17] As a prelude to doing so, we first characterize the conditions under which a VC chooses to finance the project.

Proposition 1 ***(VC's Decision on Whether or not to Finance the Project)***

(i) VC_1 will finance the project in the first round, and will continue to finance it in the second round if and only if $q_1 \geq q_1^*$.

(ii) Further, a new VC, VC_3, will finance the project in the second round if and only if $q_3 \geq q_3^*$.

The critical values, q_1^* *and* q_3^**, are characterized in Appendix A.*

Since VCs only have a prior belief about their own as well as other VCs' types when they make their investment decisions, a VC's prior belief about his own type plays an important role in deciding whether he should invest in the project in the first place. A VC will decide to start funding a project only if he assesses a high enough probability of being a low-cost VC such that his expected payoff from investing in the project is positive; otherwise, he will choose not to invest in the project at all. A similar condition applies to a new VC starting to finance a project in the second round. This occurs when one of the two VCs funding the project in the first round is excluded from financing the project in the second round (due to his shirking in the first round), so that a new VC is invited to join the syndicate.

Proposition 2 ***(Effort Provision under Syndication and Individual Contracting)***

(i) VC syndication generates higher levels of effort in both rounds relative to the case where the entrepreneur contracts with two VCs individually in each round.

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[17] Since this requires comparing across the three financing arrangements that we characterized in lemmas 1, 2, and 3, in this section, we assume that all the parametric restrictions that we specified in lemmas 1, 2, and 3 hold simultaneously.

(ii) Contracting individually with two VCs is never chosen in equilibrium by the entrepreneur as a financing mechanism in either round.

Comparing Lemma 2 and Lemma 3, it is easy to see that, in the case in which the entrepreneur contracts with two VCs individually in each round, neither VC will exert high effort (regardless of type) due to a free-rider problem. This is because, neither VC is able to observe the other VC's effort, and thus there is no credible threat of either VC being terminated or suffering a reputation loss under this arrangement. On the other hand, if the two VCs form a syndicate and contract with the entrepreneur as a team, the expected effort levels provided by the VC syndicate members will be higher because the VC will provide a high level of effort if he turns out to be of low-cost. The intuition here is that, under VC syndication, VCs can monitor each other and force the shirking VC to leave the syndicate with the cooperation of the entrepreneur. There is also an additional punishment under VC syndication, arising from VCs incurring a reputation loss B if they shirk. Thus, for a low-cost VC, the benefit of exerting high effort (discussed under Lemma 2) dominates the incremental cost of doing so, so that they choose to exert high effort in equilibrium. In summary, while the free-rider problem exists whenever there are two VCs involved, the syndicate financing structure mitigates this problem relative to the case where the entrepreneur contracts with two VCs individually. As a consequence, whenever a firm is financed by two VCs, syndication dominates individual contracting with two VCs.[18] Therefore, we will focus only on two cases hereafter: the case of VC syndicate financing and the case of single-VC financing.

[18] Of course, even under a syndicate structure, a high-cost VC will provide low effort (as we show in Lemma 2). However, since even low-cost VCs provide low effort under individual contracting, the expected level of effort is always higher under syndication than in the case where the entrepreneur contracts with two VCs individually.

Proposition 3 ***(The Choice of Syndication Sequence)***

(i) If the complexity of the firm's project in both rounds is high, i.e., $k_1 > \hat{k}_1$ *and* $k_2 > \hat{k}_2$*, then the entrepreneur chooses two VCs to finance the project under a syndicate structure in both rounds.*

(ii) If the complexity of the project in the first round is high, i.e., $k_1 > k_1^*$*, but is moderate in the second round, i.e.,* $k_2' < k_2 \leq k_2^*$*, then the entrepreneur chooses syndicate financing in the first round but chooses single-VC financing in the second round if one of the two VCs shirks in the first round.*

(iii) If the complexity of the project in the first round is low, i.e., $k_1 \leq \bar{k}_1$*, but is high in the second round, i.e.,* $k_2 > \bar{k}_2$*, the entrepreneur obtains financing from a single VC in the first round, but chooses a syndicate financing in the second round.*

(iv) If the complexity of the project is low in both rounds, i.e., $k_1 \leq \tilde{k}_1$ *and* $k_2 < \tilde{k}_2$*, then the entrepreneur chooses to obtain financing from a single VC in both rounds.*

The threshold values $\hat{k}_1, \hat{k}_2, k_1^*, k_2^*, k_2', \bar{k}_1, \bar{k}_2, \tilde{k}_1,$ *and* $\tilde{k}_2$ *are characterized in Appendix A.*

The choice of the number of VCs to finance the project and the contracting structure depend on the complexity of the project and the free-rider problem characterizing the provision of inputs by VCs when there is more than one VC involved. If the project is very complex, syndicate financing dominates single-VC financing, since, in this case, the cost advantage of the syndicate structure in providing inputs to the firm dominates its disadvantage in terms of the free-rider problem. Conversely, if the project is of low complexity, single-VC financing is the equilibrium choice, since, in this case, considerations of eliminating the free-rider problem dominate any cost disadvantage of single-VC financing. Finally, if the complexity of the project increases over time, firms that started out under single-VC financing in the first round may adopt a syndicate structure in the second round. If, on the other hand, project complexity declines over time, a firm that used a syndicate financing structure in the first round may adopt a single-VC structure in the second round if one of the VCs funding the project in the first round shirks (and is therefore excluded from further financing).[19]

Proposition 4 ***(The Effect of Syndication Sequence and Syndicate Composition Dynamics on Project Success)*** *A project financed by a syndicate constituted by the same set of VCs in both rounds will have a higher probability of success than a project financed by a syndicate with different VCs in the two rounds.*

The intuition behind this proposition is as follows. From Lemma 2, we know that a low-cost VC always provides high effort while a high-cost VC always shirks in equilibrium. Therefore, if the same group of VCs finances the project in both rounds, one can infer that both VCs are of the low-cost type, and will therefore provide high effort in both rounds. If VC syndicate members are different in the second round from those in the first round, it can be inferred that there was one VC who is of the high-cost type in the first round, thus leading to a new VC to be invited to join in the syndicate in the second round (upon the high-cost VC shirking in the first round). Consequently, the success probability of such a project will be either

[19] To give an example of a project changing in complexity over time, consider a biotech firm for which the first stage involves the development of a molecule to address a disease. The more complex second stage may involve animal and human clinical trials in order to get FDA approval for the drug. The third stage may involve the commercialization of the drug, which may involve even greater complexity. Even for a single drug, the complexity of firm activities and correspondingly, the complexity of the inputs required from the VCs financing the firm may increase (or decrease) from one round to another. See, for example, for the description of drug development in the book titled "The Cure" by Anand (2009) who provides anecdotes on developing a drug for the debilitating and life-threatening Pompe disease, where the complexity of the firm (project) went up dramatically over financing rounds.

P_M or P_L, depending on the new VC's type, which is lower than the probability of project success when the syndicate has the same set of low-cost VCs in both rounds. In summary, if a new VC is invited to join in the syndicate in the second round, it must be the case that some shirking occurred in the first round, lowering the project's success probability.

V. Implications of the Model and Testable Hypotheses

Our model generates several testable predictions which we use to develop testable hypotheses for our empirical analysis. They are discussed below. In developing our testable hypotheses, we first define the three forms of contracting between the entrepreneur and VCs, namely, contracting with a syndicate consisting of multiple VCs; contracting with an individual VC; and contracting separately with two or more VCs at the same point in time as follows. VC syndication is defined theoretically as two or more VCs coming together to take an equity stake in an investment. The syndicate's operation involves "a group of individuals who must make a common decision under uncertainty that will result in a payoff to be shared jointly among them" (Wilson (1968)). Therefore, we define VC syndication here to be a group of two or more VCs sharing any particular round of financing. In other words, under syndication, the entrepreneur contracts with a group of VCs as part of a single contract (this is observable empirically in the data). If, however, the entrepreneurial firm receives funds from only one VC in each round for all rounds, it is classified as an individual-VC-financed firm (even if different rounds involve different investing VCs) provided that the subsequent round occurs a significant period of time (more than a month) after the previous round. Finally, we define an entrepreneur contracting with multiple VCs (rather than as part of a syndicate) as a situation where an entrepreneur contracts with two or more different VCs in separate financing rounds within one month of each other: in other words, separate contracting with multiple VCs occurs almost simultaneously with each other (unlike the case of contracting with individual VCs where such contracting with various VCs is separated significantly across time). It is possible to observe this as well from the data (if such contracting takes place in practice).

1. Complexity of the project and the likelihood of syndication: Our model implies that firms with projects in industries using more complex technologies are more likely to be financed by a VC syndicate (**H_1**). To the extent that some complex projects are also riskier, a hypothesis somewhat similar to our hypothesis **H_1** may arise from the traditional diversification (risk sharing) motive for VC syndicate formation (see, e.g., Lockett and Wright (1999)).[20]

2. Syndicate membership and VC expertise: Our model predicts that VC investors with specialization only in a certain specific area (i.e., specialists) are more likely to join in a syndicate to finance entrepreneurial firms. On the other hand, VCs who have some degree of expertise in multiple areas of value creation (i.e., generalists) are more likely to invest in entrepreneurial firms alone (**H_2**). This prediction of our model arises from the fact that VCs who are specialists are likely to have relatively higher costs of providing inputs to the entrepreneurial firm outside their area of expertise compared to the cost incurred by VCs who are generalists.[21]

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[20] See also Palia, Ravid, and Reisel (2008), who show that riskier projects in the film industry are often financed through alliances. However, it is important to point out that risk and project complexity are fundamentally different, since there may be many complex projects that are not unduly risky, and many risky projects that may not be complex.

[21] To the extent that projects financed by specialized VCs can benefit from greater learning arising from the exchange of information among syndication partners (in other words, if we assume that specialized VCs are also the ones to benefit more from a "second opinion"), a prediction somewhat similar to our hypothesis **H_2** may also be generated by the "second opinion" hypothesis of Casamatta and Haritchabalet (2007).

3. Suboptimality of separate contracting with multiple VCs: Our model shows that, for an entrepreneurial firm, separate contracting with multiple VCs individually will be dominated by contracting with either a VC syndicate or with a single VC throughout all financing rounds. This implies that the likelihood of an entrepreneurial firm contracting separately with different individual VCs almost simultaneously is very small (**H_3**). We will later show (in Section VI.B.3) that such contracts are indeed very rarely observed in practice.

4. Dynamic Composition of VC syndicates across financing rounds and the probability of project success: Our model predicts that, among firms financed by a syndicate of VCs, those firms whose syndicate composition remains largely unchanged across financing rounds are more likely to have a successful exit compared to those which are financed by VC syndicates whose membership changes significantly across financing rounds (**H_4**).

VI. Empirical Analysis

In this section we present empirical tests of the three predictions of our model (testable hypotheses **H_1** to **H_4**).

A. Data and Sample Selection

We obtain data on round-by-round investments by VCs from the Thomson Venture Economics database for entrepreneurial firms that received their first round VC financing between 1990 and 2004. We exclude non-U.S. firms, firms financed by angels and VCs without identification, firms with missing or inconsistent data, and firms that receive only one round of financing before they go public, are acquired, or are written off, leaving 11,880 distinct U.S. entrepreneurial firms. The Venture Economics database provides information on the date when the firm was established, the date when it received each round of VC financing, the firm's development stage, the number of financing rounds, the number of VCs investing in the firm, and the date and type of exit (e.g., IPO, acquisition, or write-off). Specifically, we update and fill in the missing observations for the date the firm was established by using Jay Ritter's database (https://site.warrington.ufl.edu/ritter/ipo-data/) for the subset of firms that go public and the CorpTech EXPLORE database for the subset of firms that remain private.

We obtain the list of VC firms from the Venture Economics database. Our dataset contains 4,383 VCs that invest in entrepreneurial firms in the sample period. We compute two different reputation measures for each VC firm at a specific date such as financing round date, IPO date, or acquisition date: (i) the VC firm's age measured as the number of years since its date of inception, VC_FIRM_AGE; and (ii) the total dollar amount raised by the VC firm since 1965, VC_FUND_SIZE.[22]

Table 1 presents summary statistics for various variables. The median entrepreneurial firm is financed by four VC investors, is one year old when it received the first round of VC financing, receives three rounds of VC financing, receives $19.5 million from VC investors, and is operating in an industry with industry average asset tangibility of 16%, R&D/sales ratio of 4%, and market-to-book ratio of 3.96.[23]

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[22] Gompers and Lerner (1998) use the amount of funds the VC raised during the five years prior to the date of interest as a measure of VC reputation. They, however, show that venture fundraising is affected by a number of macroeconomic factors such as a tax on capital gains, demand for VC funding, the real interest rate, etc. We, therefore, use the two VC reputation measures used in Hochberg, Ljungqvist, and Lu (2007) and Chemmanur, Loutskina, and Tian (2014), instead.

[23] While, in the interest of keeping the model simple, we construct a model with only two VCs in a syndicate (and only two inputs needed for the firm to succeed), usually the free rider problem gets worse when the number of VCs gets larger, since it is easier in this case for each VC to believe that his individual effort does not matter in determining the eventual project outcome and therefore reduce his own costs by shirking. This means that the trade-

[Insert Table 1 about here.]

We define VC syndication here to be a group of two or more VCs sharing any particular round of financing. In other words, under syndication, the entrepreneur contracts with a group of VCs as part of a single contract (this is observable empirically in the data). If, however, the entrepreneurial firm receives funds from only one VC in each round for all rounds, it is classified as an individual-VC-financed firm (even if different rounds involve different investing VCs) provided that the subsequent round occurs after a significant period of time (more than a month) has elapsed after the previous round.

To proxy for industry complexity, we follow Gompers (1995) and construct average industry measures to capture characteristics of industries to which entrepreneurial firms belong. Specifically, we calculate industry asset tangibility (IND_TANG) as the average industry ratio of tangible assets (property, plant, and equipment, Compustat data item 8) to total assets (data item 6), industry R&D expenses to sales ratio (IND_R&D_SALES) as the the average industry ratio of R&D (data item 46) to sales (data item 12), and the industry market-to-book ratio (IND_MTB) as the industry average of the ratio of market value of equity (data item 199 multiplied by data item 25) to book value of equity (data item 216).[24]

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offs we model in this paper become even more important in practice relative to the pure setting of our theoretical model.

[24] Our data collection process follows Gompers (1995). We collect annual SIC industry average from Compustat for each entrepreneurial firm that received VC financing. If the four-digit SIC group has fewer than four companies, we use the three-digit industry group instead. Similarly, if the three-digit group has fewer than four companies, we collect the two-digit SIC group averages. The data are matched by date and industry to each firm.

B. Empirical Tests and Results

1. Industry Complexity and VC Investors' Propensity to Syndicate

In this section, we examine how industry complexity affects the VC investor's propensity to syndicate with other VC investors. We test hypothesis **H_1** that states that VCs are more likely to form syndicates to finance projects in more complex industries.

Table 2 reports our probit regression results with the dependent variable being the VC_SYND dummy variable that equals one if the venture is financed by a VC syndicate and zero if it is financed by individual VCs alone. We use the two industry average measures constructed earlier, namely IND_TANG and IND_R&D_SALES, as the proxies for the complexity of an industry. Following the existing literature, we assume more complex industries are more R&D intensive and use more intangible assets. In addition to the main variables of interest, we include IND_MTB and industry average sales growth (IND_SALES_GROWTH) as proxies to control for industry growth option value. We also control for entrepreneurial firm characteristics such as a firm's age (FIRM_AGE), investment amount received at the first round of financing (INV_ROUND_ONE), development stage at the first round of VC financing, VC reputation measures (VC_FIRM_AGE and VC_FUND_SIZE), and VC geographical location dummies. Finally, we include year fixed effects for the year when the firm received the first VC investment in various regressions. Standard errors are clustered at the VC firm level. We report the marginal effects of independent variables because the coefficients of probit models are usually hard to interpret.

[Insert Table 2 about here.]

Regressions in columns 1 and 2 of Table 2 show that the coefficient estimates of IND_TANG are negative and significant at the 5% level, suggesting that when more intangible assets are used in the industry, it is more likely that VCs form syndicates to finance the firm. The coefficient estimates of IND_R&D_SALES in the regressions in columns 3 and 4 of Table 2 are positive and significant at the 5% level, suggesting that firms in more R&D intensive industries are more likely to be financed by VC syndicates.

In an untabulated analysis, we replace the dependent variable in Table 2 with the number of VCs in a syndicate. Although it is not a direct test of hypothesis $\mathbf{H_1}$, it illustrates how industry complexity affects the size of VC syndicates. The coefficient estimates of IND_R&D_SALES are positive and significant at the 5% level, suggesting that more VCs tend to join syndicates to finance projects in more complex industries. Taken together, the above evidence supports hypothesis $\mathbf{H_1}$, suggesting that VCs are more likely to form syndicates when they invest in firms that are in more complex industries.

2. VC Specialization and Propensity to Syndicate

Next, we explore how the degree of VC specialization affects the VC investor's propensity to join a syndicate. We follow Gompers, Kovner, and Lerner (2009) to construct the proxies that measure the degree of VC investor's specialization: the Herfindahl index that equals the sum of the squares of the percentage of all previous investments in each of the 18 industries classified in the Venture Economics database.[25] We further distinguish between the equally-weighted and value-valued Herfindahl index. The equally-weighted Herfindahl index, EW_HERFINDAHL, equals the sum of the squares of the percentage measured as the number of

[25] The 18 industries assigned by the Venture Economics database are Agriculture/Forestry/Fish, Biotechnology, Business Services, Communications, Computer Hardware, Computer Other, Computer Software, Construction, Consumer-Related, Financial Services, Industrial/Energy, Internet-Specific, Manufacture, Medical/Health, Other, Semiconductor/Electronics, Transportation, and Utilities.

entrepreneurial firms in an industry the VC has invested in relative to the number of entrepreneurial firms in all of the VC's previous investments. The value-weighted Herfindahl index, VW_HERFINDAHL, equals the sum of the squares of the percentage measured as the funding amount in an industry the VC has invested in relative to the funding amount in all of that VC's previous investments.

[Insert Table 3 about here.]

Table 3 reports the regression results of the probit regression model with the marginal effects of independent variables reported. The dependent variable is the VC syndication dummy, VC_SYND, which equals one for VC syndication and zero if the VC invests in the firm alone. In the regression reported in column 1, the main variable of interest is the VC firm's EW_HERFINDAHL. The coefficient estimate of EW_HERFINDAHL is positive and significant at the 1% level, suggesting that VC investors with a higher degree of specialization, i.e., specialists, are more likely to join in a syndicate to finance a firm. In the regression reported in column 2, we construct a dummy variable, EW_SPECIALIST, that equals one if EW_HERFINDAHL is greater than the sample median and zero otherwise. Therefore, all VC investors with above median value of EW_HERFINDAHL are defined as specialists, and VC investors with below median value of EW_HERFINDAHL are defined as generalists. The coefficient estimate of EW_SPECIALIST is positive and significant at the 1% level, being consistent with the results reported in column 1. The magnitude of the coefficient of the EW_SPECIALIST dummy suggests that a VC specialist is 1.3% more likely to join in a VC syndicate relative to a VC generalist. We repeat the regressions in columns 3 and 4 with the main variable of interest replaced by the VW_HERFINDAHL and VW_SPECIALIST dummy, respectively. We find similar results when the value-weighted Herfindahl index is used. Overall, our evidence supports hypothesis **H_2**, suggesting that, while specialists are more likely to join a VC syndicate to finance an entrepreneurial firm, generalists are more likely to invest in the firm alone.

It is also worth noting here that the coefficient estimate of the reputation control variable ln(VC_FUND_SIZE) is negative and significant at the 1% level in all regressions in Table 3.[26] Thus, our results show that VCs who are generalists are less likely to syndicate than those who are specialists even after controlling for VC fund size, so that the difference in the propensity of the two types of VCs to syndicate is not driven solely by any differences in the financial constraints that they face in terms of funds available for investment.

3. Is Contracting Individually with Multiple VCs Prevalent in Practice?

To identify entrepreneurial firms which contracted with multiple VCs separately (rather than as part of a syndicate) over a short period of time (i.e., almost simultaneously), we searched for firms which had two or more separate financing rounds (with a different individual VC in each round) within one month of each other. The analysis of the data indicates that such individual contracting with more than one VC over a short period of time is almost non-existent in practice (it is observed in less than 0.097% of VC deals) in our sample. This observation is consistent with our hypothesis **H_3**.

4. Dynamics of VC Syndicate Composition and Entrepreneurial Firms' Propensity for a Successful Exit

Our theoretical analysis predicts that firms financed by a syndicate consisting of the same set of VC investors throughout various financing rounds are more likely to have a successful exit

[26] The coefficient estimate of the other reputation variable, ln(VC_FIRM_AGE), is negative, but not statistically significant in the regressions reported in Table 3.

compared to those that are financed by VC syndicates whose membership changes across financing rounds (hypothesis **H4**). We test this hypothesis in this section.

Following the existing VC literature (e.g., Brander et al. (2002) and Gompers et al. (2009)), we measure an entrepreneurial firm's exit outcome by constructing a successful exit dummy (SUCCESS_EXIT) that equals one if the entrepreneurial firm either goes public or is acquired and zero if the firm is written off by the VC investors. Although both IPO and acquisition are considered to be successful exit pathways, recent literature has also suggested that going public is a more desirable successful exit pathway than an acquisition for both entrepreneurs and VC firms. For example, Bayar and Chemmanur (2012) find that IPO firms enjoy a 21% "valuation premium" relative to firms being acquired, and Sahlman (1990) shows that almost all of the returns for VC investors are earned on companies that eventually go public. Therefore, as suggested by Bayar and Chemmanur (2011), only the highest quality firms may access the public capital markets through an IPO. Motivated by the above literature, we then construct an IPO exit dummy (IPO_EXIT) that equals one if the entrepreneurial firm goes public and zero if the firm is acquired or is written off by VC investors.

We construct a VC syndicate composition index (VCCI) that captures the degree of overlap of VC syndicate members across financing rounds within an entrepreneurial firm. The composition index is defined as follows: $\text{VCCI} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{t} VC_{i,j}}{\text{NVC}\times\text{NROUNDS}}$, where $VC_{i,j}$ represents the VC investor i investing in round j, NVC is the number of VC investors investing the entrepreneurial firm across all financing rounds, and NROUNDS is the number of financing rounds the entrepreneurial firm receives. The VC composition index VCCI increases as the overlap of VC investors across various financing rounds increases. For example, if an entrepreneurial firm is financed by a VC syndicate consisting of the same set of VC investors throughout all financing rounds, VCCI equals one.

Panel A of Table 4 reports the results of our regressions that examine how VC syndicate composition affects the entrepreneurial firm's propensity to have a successful exit. The dependent variable is SUCCESS_EXIT in column 1. The coefficient estimate of VCCI is positive and significant at the 5% level, which suggests that as the overlap of VC investors within a VC syndicate across various financing rounds increases, the entrepreneurial firm financed by this VC syndicate is more likely to have a successful exit. In column 2, we replace the dependent variable with IPO_EXIT and find that the coefficient estimate of the VCCI continues to be positive and significant, suggesting that, as the overlap of VCs within a VC syndicate across various financing rounds increases, the entrepreneurial firm financed by this VC syndicate is more likely to exit through an IPO rather than another form of exit.

[Insert Table 4 about here.]

An alternative interpretation of the results presented in Panel A of Table 4 is that some VCs may experience liquidity shocks due to various reasons and therefore have to withdraw their investments from their portfolio firms, reducing the firm's probability of success. Therefore, the fact that some VC investors do not participate in subsequent financing rounds may not suggest that the VC investors were shirking in the previous rounds. To examine whether our results are robust to this alternative explanation, we repeat the analysis in a subsample period, 1993-2000, when the U.S. economy was experiencing an unusually long expansion/boom. During this period, the capital supply available to VC investors was higher and VC investors were less likely to experience a liquidity shock relative to those investing during a contraction/recession period. We report the results in this subsample period in Panel B of Table 4. We find positive coefficient estimates of the VC composition index VCCI in both columns (successful exits and IPO exits), suggesting that the results hold even in the boom period when VCs' dropping out from the syndicate is less likely due to liquidity shocks. Overall, the evidence reported in Table 4 is consistent with hypothesis **H_4**, suggesting that firms financed by a syndicate with a more "constant" composition across financing rounds are more likely to have a successful exit outcome.[27]

To address the concern that the composition of VC syndicates across financing rounds is endogenous (i.e., higher quality firms will have syndicates consisting more of the same set of VCs), we make use of an instrumental variable (IV) approach. The instrument we use for the dynamics of VC syndicate composition (as measured by the VC composition index, VCCI, discussed earlier) is an industry concentration index (ICI), which was initially constructed by Kacperczyk, Sialm, and Zheng (2005) for active mutual funds and then modified and adapted by Tian (2011) to the setting of VC funds. This index measures the industry concentration of the lead VC firm's portfolio. Previous research (e.g., Brander, Amit, and Antweiler, 2002) shows that portfolio diversification is one of the most important motivations for a VC firm in deciding to co-invest in an entrepreneurial firm with other VC firms. That is, if a VC firm already has a lot of exposure to an industry, it has a strong incentive to syndicate with other VC firms to remain diversified. But if a VC firm has not previously concentrated all its investments in just a few industries, it might prefer to fund the whole deal alone. Suppose that in year t, VC firm i has

[27] The results reported in Table 4 also indicate that the positive coefficient estimate of the VC composition index VCCI is more statistically significant and larger in magnitude when the dependent variable is the IPO exit dummy (IPO_EXIT) rather than the successful exit (i.e., exit through an IPO or an acquisition) dummy (SUCCESS_EXIT).

$w_{i,t,j}$ portfolio firms in industry j (scaled by the total number of venture firms in year t).[28] There are a total of $\overline{w}_{t,j}$ venture firms in industry j (also scaled by the total number of venture firms in year t). The investment concentration of VC firm i at year t is defined as the sum of the squared deviations of $w_{i,t,j}$ from $\overline{w}_{t,j}$: $\sum_{j=1}^{18}(w_{i,t,j} - \overline{w}_{t,j})^2$.

The ICI measures by how much a VC firm's portfolio deviates from a VC's hypothetical market portfolio, which consists of all entrepreneurial firms in an industry in which a VC firm could have invested. We calculate the weighted-average ICI for entrepreneurial firms that have more than one lead VC firm. The weight is the investment by a lead VC firm as a fraction of the total VC investment received by the firm. This index equals zero if a VC firm's portfolio has exactly the same industry composition as the VC's hypothetical market portfolio, and it increases as the VC's portfolio becomes more concentrated in a few industries. To be a valid instrument, the ICI must satisfy both a relevance condition and an exclusion restriction.

[Insert Table 5 about here.]

The first-stage IV regression results reported in columns 1 and 3 of Table 5 show that our instrument ICI is strongly and positively associated with our VC composition index VCCI, satisfying the relevance condition. In other words, the first-stage results suggest that a VC firm's propensity to co-invest in a portfolio firm with more of the same set of other VC firms across multiple rounds of financing increases as the lead VC's own investments become more concentrated in a few industries. We report the F-statistic for the multivariate test of the significance of our proposed instrument (ICI) in columns 1 and 3. The value of this F-statistic is larger than the critical values for the Stock and Yogo (2005) weak instrument test based on 2SLS

[28] As discussed earlier in footnote 25, each entrepreneurial firm in a VC investment portfolio is assigned to one of 18 industries by the Venture Economics database.

size. Therefore, we reject the null hypothesis that our instrument (ICI) for the VC composition index is weak. The required exclusion restriction (that needs to be maintained theoretically) is also likely to be satisfied here, since ICI is a characteristic of the lead VC firm and is unlikely to be correlated with any aspect of the entrepreneurial firm's quality. Our second-stage IV regression results reported in Table 6 show that, even after controlling for the endogeneity of VC syndicate composition, the VC composition index VCCI has a significantly positive effect (with a p-value less than 0.10) on the probability of a successful exit (IPO or acquisition) and on the probability of an IPO exit.

In untabulated results, we repeat the IV analysis for the subsample period of 1993-2000 when the U.S. economy was in the expansion/boom period. Once again, the second-stage results of our IV regressions suggest that the VC composition index has a significant and positive effect on the probability of a successful exit or an IPO exit, suggesting that our results hold even in the boom period when VCs dropping out from the syndicate due to liquidity shocks is less likely.

VII. Conclusion

In this paper, we have developed a new rationale for the formation of VC syndicates, and theoretically analyzed the dynamics of VC syndicates. In our model, an entrepreneur needs financing from VC investors to implement his firm's positive NPV project. In addition to financing, VCs can provide the firm with two inputs (each in a different area of activity), which can increase the probability of project success: these inputs can be provided either by a single VC, or by two different VCs, each operating in his own area of expertise. We analyzed the firm's equilibrium choice between financing the project by contracting with a single VC, by contracting individually with two VCs, or by contracting with a syndicate consisting of two VCs. Our analysis generated several testable predictions for the equilibrium choice of the structure of VC financing, for the evolution of this structure across financing rounds, as well as for the dynamics of the composition of VC syndicates and for how this dynamics affects entrepreneurial firms' probability of successful exit. We also presented empirical evidence that is consistent with the predictions of our model.

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Figure 1: Sequence of Events

This figure describes the sequence of events in our theoretical model of VC financing of entrepreneurial firms.

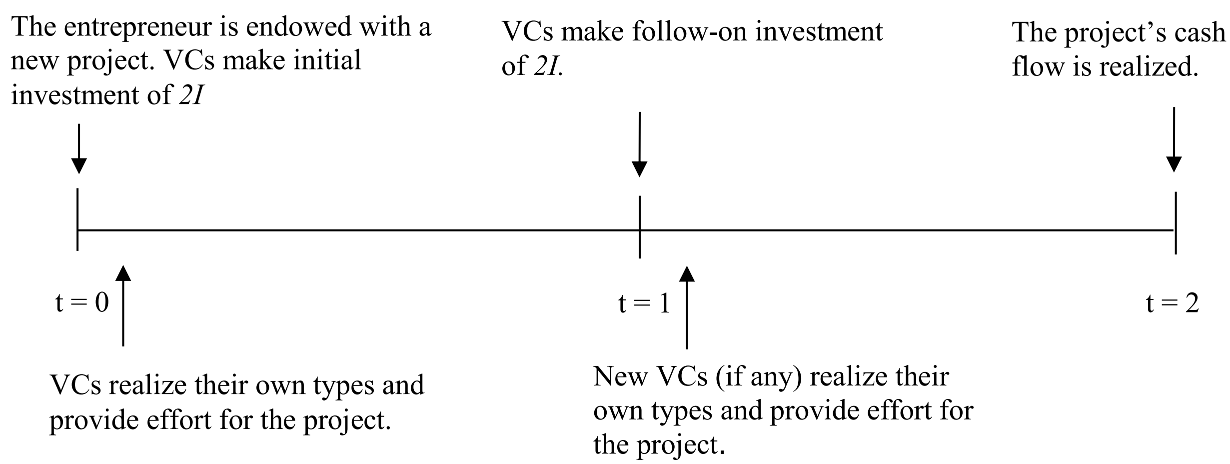

Table 1: Summary Statistics for VC Financing in Entrepreneurial Firms

This table reports the descriptive statistics for the sample of entrepreneurial firms that receive VC financing from 1990 to 2004. The main data source for entrepreneurial firms and VCs is the Thomson Venture Economics database. All variables are defined in Appendix C.

	25%	Median	Mean	75%	SD	N
NVC	3.00	4.00	5.42	7.00	3.81	11,880
FIRM_AGE	0.00	1.00	3.69	3.00	8.88	11,880
NROUNDS	2.00	3.00	4.06	5.00	2.24	11,880
INV_AMT (Million $)	7.77	19.50	36.56	43.00	66.50	11.791
SEED (%)	0.00	0.00	0.23	0.00	0.42	11,880
EARLY (%)	0.00	0.00	0.44	1.00	0.50	11,880
EXPANSION (%)	0.00	0.00	0.20	0.00	0.40	11,880
LATE (%)	0.00	0.00	0.06	0.00	0.15	11,880
BUYOUT (%)	0.00	0.00	0.07	0.00	0.25	11,880
IND_TANG (%)	0.11	0.16	0.20	0.23	0.15	11,429
IND_R&D_SALES	0.02	0.04	0.17	0.13	0.93	10,467
IND_MTB	1.69	3.96	6.83	8.18	15.85	11,429
CA_DUMMY	0.00	0.00	0.18	0.00	0.39	11,880
MA_DUMMY	0.00	0.00	0.13	0.00	0.34	11,880
VCCI	0.47	0.60	0.65	0.83	0.23	11,239
SUCCESS_EXIT	0.00	1.00	0.54	1.00	0.50	11,880
IPO_EXIT	0.00	0.00	0.12	0.00	0.29	11,880

Table 2: The Relation between Firm Complexity and VCs' Propensity to Syndicate

This table reports regressions for the VC investor's propensity to form a syndicate to finance the entrepreneurial firm. The dependent variable is the VC_SYND dummy that equals one for VC syndication and zero if the VC invests in the firm alone. The variables of interest are IND_TANG and IND_R&D_SALES. Other independent variables include the logarithm of one plus the entrepreneurial firm's age at round 1, the logarithm of the total investment amount at round 1, indicator variables for the entrepreneurial firm's development stage at round 1, the CA dummy, the MA dummy, the control variables for VC reputation, and year fixed effects. Data about entrepreneurial firms and VC investors are obtained from the Venture Economics database. All variables are defined in Appendix C. Standard errors clustered at the VC firm level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent Variable: VC_SYND				
	1	2	3	4
IND_TANG	-0.033**	-0.035**		
	(0.016)	(0.016)		
IND_R&D_SALES			0.006**	0.005**
			(0.003)	(0.002)
IND_MTB		-0.000		0.000
		(0.000)		(0.000)
IND_SALES_GROWTH		-0.000		0.000
		(0.000)		(0.000)
ln(FIRM_AGE)	-0.021***	-0.021***	-0.026***	-0.026***
	(0.003)	(0.003)	(0.003)	(0.003)
ln(INV_ROUND_ONE)	0.023***	0.021***	0.022***	0.020***
	(0.002)	(0.002)	(0.002)	(0.002)
SEED	0.065***	0.060***	0.096***	0.091***
	(0.009)	(0.009)	(0.011)	(0.011)
EARLY	0.060***	0.055***	0.078***	0.073***
	(0.008)	(0.007)	(0.008)	(0.008)
EXPANSION	0.028***	0.025***	0.047***	0.044***
	(0.008)	(0.008)	(0.009)	(0.009)
LATE	0.034***	0.029***	0.048***	0.043***
	(0.011)	(0.011)	(0.011)	(0.011)
CA_DUMMY	0.026***	0.026***	0.017	0.018
	(0.009)	(0.009)	(0.015)	(0.014)

MA_DUMMY	0.023**	0.022**	0.018	0.017
	(0.010)	(0.010)	(0.016)	(0.016)
VC reputation controls	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	9,543	9,177	9,543	9,177
Pseudo R^2	0.14	0.14	0.09	0.09

Table 3: The Relation between VC Investor Specialization and Propensity to Syndicate

This table reports regressions for the VC investor's propensity to form a syndicate to finance the entrepreneurial firm. The dependent variable is the VC_SYND dummy that equals one for VC syndication and zero if the VC invests in the firm alone. The variables of interest are EW_HERFINDAHL, EW_SPECIALIST, VW_HERFINDAHL, and VW_SPECIALIST. Other independent variables include the logarithm of one plus the entrepreneurial firm's age at round 1, the logarithm of the total investment amount at round 1, indicator variables for the entrepreneurial firm's development stage at round 1, the CA dummy, the MA dummy, the control variables for VC reputation, year fixed effects, and industry fixed effects. All variables are defined in Appendix C. Standard errors clustered at the VC firm level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent Variable: VC_SYND				
	1	2	3	4
EW_HERFINDAHL	0.022***			
	(0.008)			
EW_SPECIALIST		0.013***		
		(0.004)		
VW_HERFINDAHL			0.021***	
			(0.008)	
VW_SPECIALIST				0.014***
				(0.004)
ln(FIRM_AGE)	-0.015***	-0.015***	-0.015***	-0.015***
	(0.002)	(0.002)	(0.002)	(0.002)
ln(INV_ROUND_ONE)	0.012***	0.012***	0.012***	0.012***
	(0.001)	(0.001)	(0.001)	(0.001)
SEED	0.032***	0.032***	0.032***	0.032***
	(0.006)	(0.006)	(0.006)	(0.006)
EARLY	0.042***	0.042***	0.042***	0.042***
	(0.007)	(0.007)	(0.007)	(0.007)
EXPANSION	0.008	0.007	0.008	0.008
	(0.006)	(0.006)	(0.006)	(0.006)
LATE	0.017**	0.017**	0.017**	0.017**
	(0.008)	(0.008)	(0.008)	(0.008)
CA_DUMMY	0.021***	0.022***	0.019***	0.021***
	(0.004)	(0.004)	(0.005)	(0.004)

MA_DUMMY	0.019***	0.019***	0.021***	0.019***
	(0.005)	(0.005)	(0.004)	(0.005)
VC reputation controls				
ln(VC_FUND_SIZE)	-0.009***	-0.009***	-0.009***	-0.009***
	(0.002)	(0.002)	(0.002)	(0.002)
ln(VC_FIRM_AGE)	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	11,712	11,712	11,712	11,712
Pseudo R^2	0.139	0.139	0.139	0.140

Table 4: The Relation between the Dynamics of VC Syndicate Composition and the Propensity to have a Successful Exit

This table reports the regressions testing the relation between VC syndicate composition and an entrepreneurial firm's propensity to have a successful exit. The dependent variable is SUCCESS_EXIT in columns 1 and 3, and IPO_EXIT in columns 2 and 4. The variable of interest is the VC composition index VCCI. Other independent variables include the logarithm of one plus the entrepreneurial firm's age at round 1, the logarithm of the total investment amount at round 1, indicator variables for the entrepreneurial firm's development stage at round 1, the CA dummy, the MA dummy, the control variables for VC reputation, year fixed effects, and industry fixed effects. Data about entrepreneurial firms and VC investors are obtained from the Venture Economics database. All variables are defined in Appendix C. Standard errors clustered at the VC firm level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

	Panel A: Full Sample		**Panel B: Boom Market**	
Dependent Variable:	SUCCESS_EXIT	IPO_EXIT	SUCCESS_EXIT	IPO_EXIT
	1	2	3	4
VCCI	0.089**	0.127***	0.091*	0.123***
	(0.039)	(0.031)	(0.051)	(0.040)
ln(FIRM_AGE)	0.026***	0.018***	0.033***	0.017***
	(0.008)	(0.005)	(0.010)	(0.007)
ln(INV_ROUND_ONE)	0.004*	0.007***	0.008***	0.009***
	(0.002)	(0.002)	(0.002)	(0.002)
SEED	-0.057*	-0.058***	-0.030	-0.056**
	(0.031)	(0.019)	(0.040)	(0.023)
EARLY	-0.050**	-0.085***	-0.040	-0.086***
	(0.023)	(0.016)	(0.028)	(0.016)
EXPANSION	-0.026	-0.066***	-0.011	-0.050***
	(0.020)	(0.015)	(0.023)	(0.016)
LATE	-0.008	-0.024	0.009	-0.001
	(0.023)	(0.016)	(0.026)	(0.021)
CA_DUMMY	0.003	0.006	0.006	0.004
	(0.015)	(0.009)	(0.019)	(0.013)
MA_DUMMY	0.001	-0.025*	-0.004	-0.038**

	(0.019)	(0.014)	(0.025)	(0.017)
VC reputation controls	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	6,024	6,024	4,210	4,210
Pseudo R^2	0.08	0.10	0.07	0.11

Table 5: Instrumental Variable Analysis of the Relation between the Dynamics of VC Syndicate Composition and the Propensity to have a Successful Exit

This table reports the results of IV regressions testing the relation between VC syndicate composition and an entrepreneurial firm's propensity to have a successful exit. The second-stage dependent variable is SUCCESS_EXIT in Panel A and the IPO_EXIT in Panel B. The instrumental variable for the VC Composition index VCCI is the ICI index. The variable of interest is the VC composition index VCCI. Other independent variables include the logarithm of one plus the entrepreneurial firm's age at round 1, the logarithm of the total investment amount at round 1, indicator variables for the entrepreneurial firm's development stage at round 1, the CA dummy, the MA dummy, the control variables for VC reputation, year fixed effects, and industry fixed effects. Data about entrepreneurial firms and VC investors are obtained from the Venture Economics database. All variables are defined in Appendix C. Standard errors clustered at the VC firm level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

	Panel A: Successful Exit		**Panel B: IPO Exit**	
Dependent Variable:	VCCI	SUCCESS_EXIT	VCCI	IPO_EXIT
	1	2	3	4
VCCI		1.286*		1.110*
		(0.747)		(0.664)
ICI	0.042***		0.042***	
	(0.012)		(0.012)	
ln(FIRM_AGE)	0.009***	0.013	0.009***	0.007
	(0.002)	(0.010)	(0.002)	(0.008)
ln(INV_ROUND_ONE)	0.003***	0.000	0.003***	0.003
	(0.001)	(0.003)	(0.001)	(0.002)
SEED	-0.053***	0.014	-0.053***	-0.026
	(0.010)	(0.054)	(0.010)	(0.046)
EARLY	-0.060***	0.029	-0.060***	-0.044
	(0.009)	(0.051)	(0.009)	(0.048)
EXPANSION	-0.032***	0.018	-0.032***	-0.049
	(0.007)	(0.032)	(0.007)	(0.031)
LATE	-0.023***	0.024	-0.023***	-0.012

	(0.008)	(0.028)	(0.008)	(0.031)
CA and MA dummies	Yes	Yes	Yes	Yes
VC reputation controls	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	6,024	6,024	6,024	6,024
F-statistic ($z = 0$)	16.53***		16.53***	
Pseudo R^2	0.28	0.10	0.28	0.07

Appendix A: Proofs of Propositions

Proof of Proposition 1: (*i*) Since VCs do not know their true type when they make the investment decisions, i.e., they only have a prior belief about their own type as well as the other VC's type, the VC's prior belief (also known as VC's reputation) is critical for him to decide if she should invest in the project in the first place. Conditional on sequence 1, VC_1 decides to invest if and only if

(A.1) $$q_1\left((q_2 + (1 - q_2)[q_3 P_M + (1 - q_3)P_L])\delta R - 2I - 2C_L\right)$$
$$+(1 - q_1)\left(q_2[q_3 P_M + (1 - q_3)P_L]\frac{\delta R}{2} - I - B\right) > 0,$$

which implies $q_1 > q_1^1 \equiv \frac{I+B-q_2[q_3P_M+(1-q_3)P_L]\frac{\delta R}{2}}{\left[q_2+\left(1-\frac{3}{2}q_2\right)[q_3P_M+(1-q_3)P_L]\right]\delta R-I-2C_L+B}$. The above payoff equation is a weighted average of VC_1's expected payoffs. If VC_1 is of type L (with probability q_1), then in equilibrium he will provide a high level of effort and his payoff depends on his partner, VC_2's type. If VC_2 is of type L (with probability q_2), then the payoff for VC_1 is $\delta(R - 2I - 2C_L)$ while with the complementary probability that VC_2 is of type H, his expected payoff depends on the VC_3. The expected payoff is a weighted average of $\delta P_M R$ if VC_3 is of type L and $\delta P_L R$ if VC_3 is of type H subtracted by the investment of $2I$ and total cost of effort of $2C_L$. If, on the other hand, after the investment VC_1 finds him to be of type H, in equilibrium he shirks and his expected payoff depends on VC_2 and VC_3's type. Also, since VC_2 can observe his shirking in period 1, she also incurs a reputation loss B. Overall, he decides to invest in the project if and only if his expected payoff is greater than zero, which implies q_1 should be greater than q_1^1, the critical value for VC_1's reputation.

Conditional on sequence 2, VC_1 decides to invest if and only if his expects payoff from investing in the project is greater than zero, i.e.,

$$\text{(A.2)} \qquad q_1\left(q_2(\delta R - 2I - 2C_L) + (1-q_2)\left(P_M\frac{3}{2}\delta R - 3I - (1+k_2)C_L\right)\right)$$

$$+(1-q_1)\left(q_2\left(P_M\frac{1}{2}\delta R - I - B\right) + (1-q_2)(-I-B)\right) > 0,$$

which implies $q_1 > q_1^2 \equiv \frac{I - q_2 P_M \frac{\delta R}{2} + B}{q_2\left(\delta R\left(1-\frac{P_M}{2}\right) - I - 2C_L\right) + (1-q_2)\left(P_M\frac{3}{2}\delta R - 2I - (1+k_2)C_L\right) + B}$. Similar to the payoff equation on sequence 1, the expected payoff is a weighted average of VC_1's payoffs conditional on his true type. If VC_1 is of type L, his expected payoff depends on the type of VC_2. Unlike the situation where VC_1 is on sequence 1, if with probability $(1-q_2)$ that VC_2 is of a type H VC, then VC_1 will finance the project alone during period 2, and his payoff is $\left(P_M\frac{3}{2}\delta R - 3I - (1+k_2)C_L\right)$. If, on the other hand, VC_1 is a type H VC and VC_2 is of type L, then VC_2 will not invite VC_1 to finance the project in the second period and continue to finance the project alone in period 2, and the payoff for VC_1 is $\left(P_M\frac{\delta R}{2} - I - B\right)$; if VC_2 is of a type H VC, then the project will fail with probability 1 and the payoff of VC_1 will be $-I-B$. VC_1 calculates the weighted average of his payoff based on his prior belief about his own type and invests if and only if the expected payoff for investing the project is greater than zero, which implies q_1 should be greater than q_1^2.

If VC_1 is on sequence 3, then he decides to invest if and only if his expected payoff from investing in the project is greater than zero:

$$\text{(A.3)} \qquad q_1\left((q_3 + (1-q_3)P_H)\frac{3}{2}\delta R - 3I - (k_1+1)C_L\right) + (1-q_1)(-2I) > 0,$$

which implies $q_1 > q_1^3 \equiv \frac{2I}{(q_3+(1-q_3)P_H)\frac{3}{2}\delta R - I - (k_1+1)C_L}$.

Finally, if VC_1 is on sequence 4, he will choose to invest in the project for any value of q_1, since

(A.4) $$q_1[\delta 2R - 4I - (k_1 + k_2)C_L] + (1 - q_1)[\delta 2R - 4I - (k_1 + k_2)C_H] > 0.$$

Overall, if VC_1's reputation is high enough, i.e., $q_1 \geq q_1^*$, where $q_1^* = \max(q_1^1, q_1^2, q_1^3)$, she will decide to invest in the project at time 0 no matter the sequence she is going to follow.

(*ii*) The same choice is also faced by VC_3, who is invited to join the syndicate in period 2. There are two scenarios under which VC_1 will invite VC_3 to join the syndicate: either it is on sequence 1 and VC_2 shirked during period 1 or it is on sequence 3. We will discuss these two cases separately.

If the VC syndicate is on sequence 1 and VC_2 shirked during period 1, then VC_3 agrees to join the syndicate if and only if his expected payoff from jointing the project is greater than zero, i.e.,

(A.5) $$q_3\left(P_M\frac{\delta R}{2} - I - C_L\right) + (1 - q_3)\left(P_L\frac{\delta R}{2} - I - B\right) > 0,$$

which implies $q_3 > q_3^1 \equiv \frac{I + B - P_L\frac{\delta R}{2}}{(P_M - P_L)\frac{\delta R}{2} - C_L + B}$. When VC_1 invites VC_3 join the syndicate at time 1, VC_3 knows that VC_1 of type L with probability 1 since if both VCs are type H the project will be liquidated by the end of period 1. Therefore, his expected payoff purely depends on his own type and equals the weighted average of payoff corresponding to his own type.

If VC syndicate is on sequence 3 and VC_3 can observe that there is only VC_1 backed the firm during period 1, then she will join the project if and only if

(A.6) $$q_3\left(\frac{\delta R}{2} - I - C_L\right) + (1 - q_3)\left(P_H\frac{\delta R}{2} - I - B\right) > 0,$$

which implies $q_3 > q_3^2 \equiv \frac{I + B - P_H\frac{\delta R}{2}}{(1 - P_H)\frac{\delta R}{2} - C_L + B}$. In this case, VC_3 knows that VC_1 financed the project alone during period 1, and infers that VC_1 is of type L. Therefore VC_1's expected payoff depends on his own type only. Overall, if VC_3's reputation is high enough, i.e., $q_3 \geq q_3^*$, where $q_3^* =$

$\max(q_3^1, q_3^2)$, she will decide to join the syndicate at time 1 no matter the sequence the VC syndicate follows. **Q.E.D.**

Proof of Proposition 2: The proofs of both parts (i) and (ii) directly follow from Lemma 2 and Lemma 3. Since VC syndication generates higher levels of VC effort in both rounds relative to the case in which the entrepreneur contracts with two VCs individually, this means that the firm's probability of success at the end of period 2 and therefore, the entrepreneur's expected payoff are greater in the case the entrepreneur contracts with a VC syndicate than in the case he contracts with two VCs individually. **Q.E.D.**

Proof of Proposition 3: In round 2, if VC_1 finds VC_2 that shirks in period 1, he needs to decide if he should invite a new VC to join the syndicate or back the project alone in period 2. At this point, VC_1 already knows that he is of type L. If he invites VC_3 to back the firm, his expected payoff at period 2 is $(q_3 P_M + (1 - q_3) P_L)\delta R - I - C_L$, and if he decides to back the project alone, his expected payoff at period 2 is $P_M \frac{3}{2} \delta R - 2I - k_2 C_L$. Therefore, as long as the project is complicated enough, i.e., $k_2 > \tilde{k}_2 \equiv \frac{\left[\left(\frac{3}{2} - q_3\right) P_M - (1 - q_3) P_L\right] \delta R - I}{C_L} + 1$, then VC_1 decides to syndicate with VC_3 to back the project in period 2.

If VC_1 finances the project alone in period 1, the project can continue into the next round only if the type of VC_1 is L. Then at time 1, VC_1 needs to decide if he should invite VC_3 to form the syndicate in period 2. He is facing the same tradeoff as in the previous case and the only difference is that he has different payoff structures because he finances the project alone in period 1 and therefore has a higher claim for the project's return. If he invites VC_3 to join the syndicate, his expected payoff at the end of period 2 is $[q_3 + (1 - q_3) P_H] \frac{3}{2} \delta R - I - C_L$, and if he decides to finance the project alone, his expected payoff in period 2 is $2\delta R - 2I - k_2 C_L$.

Therefore, as long as the project is complex enough, i.e., $k_2 > \bar{k}_2 \equiv \frac{\left[2-\frac{3}{2}(q_3+(1-q_3)P_H)\right]\delta R - I}{C_L} + 1$, VC$_1$ decides to invite VC$_3$ to finance the project in period 2. By simple algebra, we then can show that $\tilde{k}_2 - \bar{k}_2 > 0$. Consequently, there are three possible parameter regions for k_2 in period 2: if $k_2 > \tilde{k}_2$ then VC$_1$ will always syndicate with another VC in period 2; if $\tilde{k}_2 \geq k_2 > \bar{k}_2$, VC$_1$ will invite a new VC to syndicate for period 2 if he backs the project alone in period 1 or he will back the project alone in period 2 if he syndicated with VC$_2$ and VC$_2$ shirked in period 1; if $k_2 \leq \bar{k}_2$, the project does not need too much expertise in period 2 and therefore VC$_1$ will prefer to invest alone in period 2. We will further discuss the VC$_1$'s choice in period 1, based on different regions of k_2 documented above.

If $k_2 > \tilde{k}_2$, knowing that he will syndicate with VC$_3$ in period 2 if he provides a high level of effort in period 1, the expected payoff if he chooses to finance the project alone in period 1 is $q_1\left([q_3 + (1-q_3)P_H]\frac{3}{2}\delta R - 3I - (k_1+1)C_L\right) + (1-q_1)(-2I)$. On the other hand, if she chooses to finance the project with VC$_2$ in period 1, then his expected payoff will be:

$$q_1\left(\left(q_2 + (1-q_2)(q_3P_M + (1-q_3)P_L)\right)\delta R - 2I - 2C_L\right) + (1-q_1)\left(q_2[q_3P_M + (1-q_3)P_L]\frac{\delta R}{2} - I - B\right).$$

Therefore, if $k_1 > k_1^1$, where

$$k_1^1 \equiv \frac{q_1\left(\frac{3}{2}[q_3+(1-q_3)P_H] - \left(q_2+(1-q_2)(q_3P_M+(1-q_3)P_L)\right)\delta R - I\right) + (1-q_1)\left(-q_2[q_3P_M+(1-q_3)P_L]\frac{\delta R}{2} - I + B\right)}{q_1C_L} + 1,$$

the project is complex enough such that VC$_1$ does not have all the expertise the project needs and she invites VC$_2$ to form the syndicate to finance the project in period 1.

If $\tilde{k}_2 \geq k_2 > \bar{k}_2$, then VC$_1$ will back the project alone in period 2 if he syndicated with VC$_2$ and VC$_2$ shirked in period 1. On the other hand, VC$_1$ will choose to syndicate with VC$_3$ in period 2 if he backs the project alone in period 1. If VC_1 chooses to finance the project alone in period 1, his expected payoff will be:

$$q_1\left([q_3+(1-q_3)P_H]\frac{3}{2}\delta R-3I-(k_1+1)C_L\right)+(1-q_1)(-2I).$$

If VC_1 chooses to syndicate with VC_2 in period 1, his expected payoff will be $q_1[q_2(\delta R-2I-2C_L)+(1-q_2)\left(P_M\frac{3}{2}\delta R-3I-(1+k_2)C_L\right)]+(1-q_1)\left(q_2P_M\frac{\delta R}{2}-I-B\right)$. Therefore, under this case, if $k_1>k_1^2$, where

$$k_1^2\equiv\frac{\left[\left(\frac{3}{2}(q_3+(1-q_3)P_H)-\left(q_2+(1-q_2)\frac{3}{2}P_M\right)\right)\delta R-q_2I\right]}{C_L}-\frac{(1-q_1)\left(q_2P_M\frac{\delta R}{2}+I-B\right)}{q_1C_L}+q_2+k_2(1-q_2),$$

then VC_1 decides to form the syndicate to back the project in period 1.

If $k_2\le\bar{k}_2$, then the project is not very complex in period 2 and the VC_1 will choose to finance the project alone in period 2 if he financed the project alone in period 1. Similarly, if a VC syndicate finances the project in period 1 and VC_2 shirks, then VC_1 will choose to finance the project alone in period 2. If VC_1 chooses to finance the project alone in period 1, then his expected payoff is $\delta 2R-4I-(k_1+k_2)(q_1C_L+(1-q_1)C_H)$. If VC_1 chooses to syndicate with VC_2 to back the project in period 1, then his expected payoff is $q_1\left(q_2(\delta R-2I-2C_L)+(1-q_2)\left(P_M\frac{3}{2}\delta R-3I-(1+k_2)C_L\right)\right)+(1-q_1)\left(q_2P_M\frac{\delta R}{2}-I-B\right)$. Therefore, in this case, if $k_1<k_1^3$, where

$$k_1^3\equiv\frac{\left(2-q_1\left(q_2+(1-q_2)\frac{3}{2}P_M\right)+(1-q_1)q_2\frac{P_M}{2}\right)\delta R-\left(5-q_1(4-q_2)\right)I-(1-q_1)B}{q_1C_L+(1-q_1)C_H}$$
$$-k_2+\frac{q_1\left(2q_2+(1-q_2)(1+k_2)\right)C_L}{q_1C_L+(1-q_1)C_H},$$

then VC_1 will choose to back the project alone in period 1.

Let $\hat{k}_1 = k_1^1, \hat{k}_2 = \tilde{k}_2, k_1^* = \min(k_1^2, k_1^3)$, $k_2' = \bar{k}_2, k_2^* = \tilde{k}_2, \bar{k}_1 = \min(k_1^1, k_1^2)$, and $\tilde{k}_1 = k_1^3$. To ensure that the participation and the incentive compatibility constraints of the VCs hold in equilibrium, the entrepreneur will choose between a single VC financing the firm alone, a VC syndicate financing, and two VCs individually financing the firm based on the parameter regions specified above. **Q.E.D.**

Proof of Proposition 4: The proof directly follow from Lemma 2. **Q.E.D.**

Appendix B: Proofs of Lemmas

Proof of Lemma 1: If a VC finances the firm's project alone in each period, his payoff is $(\delta 2R - 4I - (k_1 + k_2)C_i)$ if she provides a high level of effort in each period. If the VC exerts a low level of effort only in period 2, his payoff is $(P_L\delta 2R - 4I - k_1 C_i)$. If the VC exerts a low level of effort in period 1, his payoff will be 0 no matter what his level of effort is in period 2. Since $C_H > C_L$, the VC will always provide high effort if $2(1 - P_L)\delta R > k_2 C_H$. **Q.E.D.**

Proof of Lemma 2: We first prove that if a VC syndicate finances the project in each period and both VCs provided a high level of effort in period 1, then a VC provides a high level of effort if she is of type L and provides a low level of effort if she is of type H. In this scenario, the entrepreneur chooses the contracting structure of the VC syndication. If both VCs provided a high level of effort in period 1, then the probability of a project's success will follow that shown in assumptions (1) – (9) and the expected payoff matrix for VCs in the syndicate in period 2 is going to be:

	H	L
H	$\delta R - I - C_i,\ \delta R - I - C_i$	$\delta P_H R - I - C_i,\ \delta P_H R - I - B$
L	$\delta P_H R - I - B,\ \delta P_H R - I - C_i$	$\delta P_L R - I - B,\ \delta P_L R - I - B$

It follows that if $C_L < B + (1 - P_H)\delta R < C_H$ and $C_L < B + (P_H - P_L)\delta R < C_H$, it is privately optimal for a type H VC to exert low effort in period 2, and it is privately optimal for a type L VC to exert high effort in period 2, regardless of the effort level of the other VC.

Similarly, conditional on effort levels (H, L) in period 1, the expected payoff matrix for VCs in the syndicate in period 2 is going to be:

	H	L
H	$\delta P_H R - I - C_i,\ \delta P_H R - I - C_i$	$\delta P_M R - I - C_i,\ \delta P_M R - I - B$
L	$\delta P_M R - I - B,\ \delta P_M R - I - C_i$	$\delta P_L R - I - B,\ \delta P_L R - I - B$

In this case, it follows that if $C_L < B + (P_M - P_L)\delta R < C_H$ and $C_L < B + P_L\delta R < C_H$, it is privately optimal for a type H VC to exert low effort in period 2, and it is privately optimal for a type L VC to exert high effort in period 2, regardless of the effort level of the other VC.

We then characterize the VC's equilibrium choices of effort provision in period 1 when they have made investment in the project and realized their own type but they have no information about the type of the other VC in the syndicate.

If both VCs are on sequence 1 and the VC syndicate has the same VC's identity as those in the period 1, then it can be inferred that both VCs are of type L. If, on the other hand, the VC syndicate has different VC membership in period 2 from it in period 1, then it can be inferred that one VC shirks in period 1 and a new VC is invited to join the syndicate in period 2. Going back to period 1, if a type L VC exerts a high level of effort, his expected payoff is $(q_2 + (1-q_2)q_3P_M + (1-q_2)(1-q_3)P_L)\delta R - 2I - 2C_L$. Note that his expected payoff depends on not only his own effort, but also on his partners' types and equilibrium effort levels. If he shirks in period 1, his expected payoff is $q_2(q_3P_M + (1-q_3)P_L)\frac{\delta R}{2} - I - B$. For the type L VC to exert a high level of effort in period 1, we need to ensure that

(B.1) $$C_L < C_L^1 \equiv \frac{1}{2}\left(\delta R\left[q_2 + \left(1 - \frac{3}{2}q_2\right)(q_3P_M + (1-q_3)P_L)\right] - I + B\right),$$

If the VC is of type H, then his expected payoff conditional on exerting a high level of effort would be $(q_2P_H + (1-q_2)q_3P_L)\delta R - 2I - B - C_H$. If he shirks, his expected payoff is $q_2(q_3P_M + (1-q_3)P_L)\frac{\delta R}{2} - I - B$. Thus, the type H VC shirks in period 1 if and only if

(B.2) $$C_H > C_H^1 \equiv \delta R\left(q_2P_H - \frac{q_2q_3}{2}P_M + \left((1-q_2)q_3 - \frac{q_2(1-q_3)}{2}\right)P_L\right).$$

If both VCs are on sequence 2, then a type L VC's expected payoff conditional on exerting a high level of effort in period 1 is $q_2(\delta R - 2I - 2C_L) + (1-q_2)\left(\frac{3}{2}P_M\delta R - 3I - \right.$

$(1+k_2)C_L\Big)$, and his expected payoff conditional on shirking is $q_2 P_M \frac{\delta R}{2} - I - B$. Thus, the type L VC exerts a high level of effort in period 1 if and only if

(B.3) $$C_L < C_L^2 \equiv \frac{\delta R\left(q_2 + \left(\frac{3}{2} - 2q_2\right)P_M\right) - (2-q_2)I + B}{1 + q_2 + (1-q_2)k_2}.$$

If a VC is of type H, his expected payoff conditional on exerting a high level of effort in period 1 is $q_2(P_H\delta R - 2I - B - C_H) + (1-q_2)\left(\frac{3}{2}P_M\delta R - 3I - (1+k_2)C_H\right)$. If the type H VC shirks in period 1, his expected payoff is $q_2 P_M \frac{\delta R}{2} - I - B$. Thus, for the type H VC to shirk in period 1, it must be the case that

(B.4) $$C_H > C_H^2 \equiv \frac{\delta R\left(q_2 P_H + \left(\frac{3}{2} - 2q_2\right)P_M\right) - (2-q_2)I + (1-q_2)B}{1 + (1-q_2)k_2}.$$

If VCs are on sequence 3, a type H VC's payoff conditional on exerting a high level of effort in period 1 is $\frac{3}{2}\delta R(q_3 P_H + (1-q_3)P_L) - 3I - B - k_1 C_H$, and his payoff conditional on shirking is $-2I$. Thus, the type H VC will shirk in period 1 if

(B.5) $$C_H > C_H^3 \equiv \frac{\frac{3}{2}\delta R(q_3 P_H + (1-q_3)P_L) - I - B}{k_1}.$$

If the first VC is of type L, his expected payoff if he shirks is $-2I$. If the type L VC exerts a high level of effort, his expected payoff is $\frac{3}{2}\delta R[q_3 + (1-q_3)P_H] - 3I - (k_1+1)C_L$. Thus, the type L VC will exert the high level of effort if

(B.6) $$C_L < C_L^3 \equiv \frac{\frac{3}{2}\delta R(q_3 + (1-q_3)P_H) - I}{(1+k_1)}.$$

Therefore, let $C_L \leq C_L^*$, where

(B.7) $$C_L^* = \min(B + P_L\delta R, B + (P_M - P_L)\delta R, B + (1-P_H)\delta R, C_L^1, C_L^2, C_L^3),$$

and $C_H > C_H^*$, where

(B.8) $$C_H^* = \max(B + P_L\delta R, B + (P_H - P_L)\delta R, B + (1-P_H)\delta R, C_H^1, C_H^2, C_H^3).$$

If $C_L \leq C_L^*$ and $C_H > C_H^*$, and the entrepreneur chooses a VC syndicate structure in one or both of the financing rounds in periods 1 and 2, then a VC provides a low level effort if she is of type H and a high level of effort is she is of type L in each period. **Q.E.D.**

Proof of Lemma 3: In this scenario, both VCs contract with the entrepreneur individually and VCs either cannot observe each other's effort level or cannot convince entrepreneurs when they observe the other VC shirks. We will work backward, first analyzing each VC's effort provision decision in period 2, assuming various scenarios of effort provided in period 1. In period 2, if both VCs provided high effort during period 1 (although they cannot observe the other VC's effort level at this time), then each VC's payoff is $(\delta R - I - C_i)$; if one VC provides high effort while the other VC shirks, the payoff for the working VC is $(\delta P_H R - I - C_i)$ and the payoff for the shirking VC is $(\delta P_H R - I)$; if both VCs shirk then the payoff for both of them is $(\delta P_L R - I)$. The payoff matrix is:

	H	L
H	$\delta R - I - C_i, \delta R - I - C_i$	$\delta P_H R - I - C_i, \delta P_H R - I$
L	$\delta P_H R - I, \delta P_H R - I - C_i$	$\delta P_L R - I, \delta P_L R - I$

where the left upper cell represents the case in which both VCs exert a high level of effort in period 2 and the right lower cell represents the case in which both VCs exert a low level of effort in period 2. If $(P_H - P_L)\delta R < C_L$ and $(1 - P_H)\delta R < C_L$, then it is privately optimal for each of the VCs to shirk in period 2 by exerting effort level L regardless of the effort level of the other VC.

Now consider the case where one VC provides high effort and the other VC shirked during period 1. In this case, the payoff if both of them provide a high level of effort in period 2 is $(\delta P_M R - I - C_i)$; if one VC provides high effort while the other VC shirks, the payoff for the

VC providing high effort is $(\delta P_L R - I - C_i)$ and the payoff for the shirking VC is $(\delta P_L R - I)$; if both VCs shirk then the payoff for both of them is $-I$. The expected payoff matrix in period 2 is:

	H	L
H	$\delta P_M R - I - C_i, \delta P_M R - I - C_i$	$\delta P_L R - I - C_i, \delta P_L R - I$
L	$\delta P_L R - I, \delta P_L R - I - C_i$	$-I, -I$

Thus, it follows that if $P_L \delta R < C_L$ and $(P_M - P_L)\delta R < C_L$, then it is privately optimal for each of the VCs to shirk in period 2 by exerting effort level L regardless of the effort level of the other VC. The condition $(P_M - P_L)\delta R < C_L$ is satisfied if $(P_H - P_L)\delta R < C_L$.

If none of the two VCs exerted a high level of effort in period 1, then the project will fail with probability 1 and no VC will exert a high level of effort in period 2.

Combining the above scenarios, if $(1 - P_H)\delta R < C_L, (P_H - P_L)\delta R < C_L$, and $P_L \delta R < C_L$, then the unique Nash equilibrium is (L, L) in period 2 if the entrepreneur chooses to contract with VCs individually. Given the Nash equilibrium strategies in period 2, the expected payoff matrix in period 1 is given by:

	H	L
H	$\delta P_L R - 2I - C_i, \delta P_L R - 2I - C_i$	$-I - C_i, -I$
L	$-I, -I - C_i$	$-I, -I$

It follows that (L, L) is also the unique Nash equilibrium in period 1 if $P_L \delta R < C_L$. We define the threshold value $\overline{C}_L$ as

(B.9) $$\overline{C}_L \equiv \max((1 - P_H), (P_H - P_L), P_L)\delta R.$$

Q.E.D.

Appendix C: Definitions of Variables and Parameters

Variables and Parameters used in the Theoretical Analysis

$2I$: investment amount required for the entrepreneurial firm in each financing round;

e_{ij}: level of effort provided by VC_i in period j, takes a value of H or L, where $H > L = 0$;

C: cost of exerting a high level of effort by a VC, where $C \in \{C_H, C_L\}$;

C_H: cost of exerting a high level of effort by a type H VC;

C_L: cost of exerting a high level of effort by a type L VC; $0 < C_L < C_H$;

q_i: prior belief that VC_i is of type L;

$2R$: project cash flow at time 2 if the project succeeds;

δ: fraction of project cash flows received by VCs at time 2 if the project succeeds;

k_j: complexity of the project in round $j = 1, 2$; if a single VC provides both inputs in round j, his aggregate cost of exerting high effort is $k_j C, C \in \{C_H, C_L\}, j = 1{,}2$, where $k_j > 2$;

B: reputation loss incurred by a VC syndicate member if he shirks in a financing round;

P_H: high probability of project success;

P_M: medium probability of project success;

P_L: low probability of project success.

Variables used in the Empirical Analysis

NVC: the number of VC investors co-investing in an entrepreneurial firm;

FIRM_AGE: the age of the entrepreneurial firm when it receives the first round VC financing;

ln(FIRM_AGE): equals the natural logarithm of one plus an entrepreneurial firm's age when it receives the first round of VC financing;

NROUNDS: the number of financing rounds an entrepreneurial firm receives;

INV_AMT: total amount of financing an entrepreneurial firm receives;

ln(INV_ROUND_ONE): equals the natural logarithm of the amount of financing an entrepreneurial firm receives in its first round of VC financing;

SEED: a dummy that equals one if the firm is at the seed stage when it receives the first round VC financing and zero otherwise;

EARLY: a dummy that equals one if the firm is at the early stage when it receives the first round VC financing and zero otherwise;

EXPANSION: a dummy that equals one if the firm is at the expansion stage when it receives the first round VC financing and zero otherwise;
LATE: a dummy that equals one if the firm is at the late stage when it receives the first round VC financing and zero otherwise;
BUYOUT: a dummy that equals one if the firm is at the buyout stage when it receives the first round VC financing and zero otherwise;
IND_TANG: the average industry ratio of property, plant, and equipment (Compustat item 8) to total assets;
IND_R&D_SALES: the average industry ratio of R&D (Compustat item 46) to sales (item 12);
IND_MTB: the average industry ratio of the market value of equity (Compustat item 199 multiplied by item 25) to book value of equity (item 216);
IND_SALES_GROWTH: the average industry sales growth rate in the three years preceding the first round VC financing;
CA_DUMMY: a dummy that equals one if the VC firm is in California state and zero otherwise;
MA_DUMMY: a dummy that equals one if the VC firm is in Massachusetts state and zero otherwise;
EW_HERFINDAHL: the VC investor's industry Herfindahl index that is equal to the sum of the squares of the percentage measured as the number of entrepreneurial firms in an industry the VC has invested in relative to the number of entrepreneurial firms in all of the VC's previous investments;
VW_HERFINDAHL: the VC investor's industry Herfindahl index that is equal to the sum of the squares of the percentage measured as the funding amount in an industry the VC has invested in relative to the funding amount in all of that VC's previous investments;
EW_SPECIALIST: a dummy that equals one if EW_HERFINDAHL is greater than the sample median and zero otherwise;
VW_SPECIALIST: a dummy that equals one if VW_HERFINDAHL is greater than the sample median and zero otherwise;
ln(VC_FUND_SIZE): VC reputation control variable that equals the natural logarithm of the total dollar amount raised by the VC firm since 1965;
ln(VC_FIRM_AGE): VC reputation control variable that equals the natural logarithm of one plus a VC firm's age when the entrepreneurial firm receives the first round of financing from the VC

firm. A VC firm's age is constructed as the number of years between the VC firm's founding year and the venture round year;

VCCI: the VC composition index (VCCI) is a proxy that captures the degree of overlap of VC syndicate members across all financing rounds an entrepreneurial firm receives; it equals $\frac{\sum_{i=1}^{n}\sum_{j=1}^{t} VC_{i,j}}{\text{NVC}\times\text{NROUNDS}}$, where $VC_{i,j}$ represents the VC investor i investing in round j, NVC is the number of VC investors investing the entrepreneurial firm across all financing rounds, and NROUNDS is the number of financing rounds the entrepreneurial firm receives;

SUCCESS_EXIT: a dummy that equals one if the entrepreneurial firm goes public or is acquired and zero otherwise;

IPO_EXIT: a dummy that equals one if the entrepreneurial firm goes public and zero otherwise;

ICI: industry composition index (ICI) is an index, which is constructed based on the industry classification of Venture Economics database. The Venture Economics database classifies all entrepreneurial firms into 18 industries: Agriculture/Forestry/Fish, Biotechnology, Business Services, Communications, Computer Hardware, Computer Other, Computer Software, Construction, Consumer-Related, Financial Services, Industrial/Energy, Internet-Specific, Manufacture, Medical/Health, Other, Semiconductor/Electronics, Transportation, and Utilities. Suppose that in year t, VC firm i has $w_{i,t,j}$ portfolio firms in industry j (scaled by the total number of venture firms in year t). There are a total of $\overline{w}_{t,j}$ venture firms in industry j (also scaled by the total number of venture firms in year t). The investment concentration of VC firm i at year t is defined as the sum of the squared deviations of $w_{i,t,j}$ from $\overline{w}_{t,j}$: $\sum_{j=1}^{18}(w_{i,t,j} - \overline{w}_{t,j})^2$;

VC_SYND: VC syndication dummy that equals one for VC syndication and zero if the VC invests in the firm alone.