How Are Venture Capitalists Rewarded? The Economics of Venture Capital Partnerships*

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Abstract

We model conditions under which investors pay venture capitalists (VCs) for project screening. Investors' demand will depend on their beliefs about the accuracy of the VC screening process and their expected revenue without the VC. The quality of screening will depend on VCs' information, incentives, and expected profits. We characterize equilibrium prices that VCs charge for their services and both VCs' and investors' payoff schedules. We calibrate our model using data from existing studies and find results that match the management fees charged by real-world VCs and the industry returns. Our analysis provides new insights into the formation of VC–investor partnerships and suggests that the services provided by VCs may improve capital markets efficiency.

JEL Classification Numbers: G32.
Keywords: Venture capitalists, project screening, capital markets efficiency, model calibration.

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1 Introduction

Venture capital financing is a fast-growing segment of the capital markets landscape. In 2008 alone, venture-backed companies accounted for 12 million jobs in the U.S. (11% of all private sector employment) and nearly $3 trillion in gross revenues (21% of the country's GDP).[1] Despite their relevance, relatively little is known about how venture capital funds emerge, how they set their fee structures, and how they benefit the capital markets. Although a number of stylized facts about the world of venture capitalists (VCs) are well documented, research in the area lacks a theoretical framework that explains important elements of the venture capital industry.

VC-financing arrangements typically bring together young, entrepreneurial firms and investors with limited industry or project expertise. Rather than investing directly in those firms, investors hire agents with some degree of expertise (venture capitalists) through a venture capital fund (VCF).[2] VCs screen companies and report on the value potential and progress of various ventures. A typical VCF makes investments in several stages, with ventures often abandoned in early stages when initial returns are low. During the life of the VCF, the VC commonly contributes to a very small part of the fund (around 1%) and receives an annual management fee of 1.5% to 3% of the committed capital (see Gompers and Lerner (1999) and Kaplan and Schoar (2005)). Besides the fixed compensation, the VC receives a variable portion that depends on the realized profit of the investment. When the venture is successful, the VC receives approximately 20% of the profit (usually through an IPO).

While relatively well documented, many questions arise about the set of relationships and payoffs that characterize venture capital partnerships. Under what circumstances are investors willing to pay for the services VCs provide? Do standard contracts give sufficient incentives for VCs to produce accurate reports? What explains the observed payment structures in the VC industry? Do VCFs increase the efficiency of financial markets?

This paper provides a step forward in answering these questions by characterizing equilibrium conditions in which investors pay VCs to perform project screening. VCs are special to the extent that they *may* be in a better position to determine whether entrepreneurs are knowledgeable about the quality of their projects. Because VCs' information might increase the expected gain from project funding, investors are willing to pay for screening so long as VC reports are sufficiently accurate. In exchange, VCs charge investors part of the surplus brought about by screening. We formalize equilibrium conditions in which VCs will increase the probability that good projects are financed and reduce the probability that bad projects receive funding, increasing market efficiency. We also characterize the payoff schedules of VCs and investors under a VCF partnership. To our knowledge, this is the first paper to formally model investors, VCs, and entrepreneurs in a single

[1] See *Global Insight* (2009) for additional statistics about the venture capital industry.

[2] According to the National Venture Capital Association, the typical VC specializes in deals involving industries in which he or she has years of prior experience (VCs are oftentimes former entrepreneurs in those industries).

framework, jointly characterizing the conditions for emergence of VCFs, the payoffs of the various participants of VCFs, and the efficiency of VC financing.

Let us discuss the intuition underlying our model. We consider a world in which investors are uninformed about the quality of any specific projects, while entrepreneurs may be either informed or uninformed about the quality of their projects. If investors choose to finance entrepreneurs directly, they can offer contracts demanding high returns, which only informed entrepreneurs with good projects accept; or low returns, which attract all types of entrepreneurs. If it is optimal to demand high returns, uninformed entrepreneurs with good projects will not be financed; while if it is optimal to demand low returns, bad projects will be financed and the investor loses the extra rent from informed entrepreneurs with good projects. VCs may increase investors' expected payoff by screening informed and uninformed entrepreneurs and identifying good and bad projects. The reports provided by VCs, if accurate, synchronize the beliefs of both investors and entrepreneurs about projects. This increases the willingness of entrepreneurs with good projects to accept contracts that demand high returns, increasing investors' expected payoff. Investors pay for VC services to the extent that reports are sufficiently accurate in reflecting information gleaned through screening. VC reports, however, may not be accurate.

In solving the model, we use the concept of a Perfect Bayesian Equilibrium. Under this concept, sequential rationality implies that VC reports maximize the probability of new rounds of financing so as to generate higher levels of carried interest. If these reports are believed, they might cause over-investment and a conflict of interests arises between investors and VCs. The problem is less severe when the signals of VCs about the quality of ventures are highly correlated with those of entrepreneurs.[3] In this case, most of the uncertainty of VCs about projects is resolved and the gains associated with misreporting are reduced. The types of equilibria that arise are payoff-equivalent, with payoffs equal to those that arise in equilibria in which VCs make accurate reports about the business they invest in. The problem is more challenging when VCs are less certain about the types of the entrepreneurs. In this case, equilibria with different payoffs and efficiency properties arise. We refine the set of equilibria using the "announcement-proof" criterion proposed by Matthews et al. (1991) to obtain a unique outcome. The only equilibria that survive this criterion have VCs issuing less than accurate reports. Although VCs misreport in equilibrium, reports are accurate enough so as to adjust the beliefs of investors and entrepreneurs about the quality of ventures. This allows for higher surplus extraction from uninformed entrepreneurs with high-quality ventures and increases investors' expected profits under the VC arrangement. Under both VC-information scenarios, VCFs emerge as optimal arrangements. The management fees that VCs receive are given by the surplus that screening creates.

Under a VC-equilibrium in which the signals of entrepreneurs and VCs are highly correlated,

[3]This happens when VCs are informed about project quality and about entrepreneurs' knowledge of project quality.

higher returns are required from informed entrepreneurs with good projects and lower returns are demanded from uninformed entrepreneurs. It follows that market efficiency is increased with the VC-equilibrium in that a greater proportion of good projects is financed. When the signals of VCs and entrepreneurs are less correlated, VCs might have only slightly finer information about the quality of projects. Yet, reports are accurate enough so that uninformed entrepreneurs with good and bad projects adjust their beliefs, with the former accepting contracts with higher returns and the latter rejecting contracts. This further increases efficiency. Crucially, although VCs may have some informational advantage over the investor, we do not require VCs to be fully-informed agents. Notably, we show that VCs may help reduce inefficiencies even when VCs have *no information advantage* about the projects they help finance.

The empirical counterpart for the price of screening in our model is the management fee charged by VCs on the committed capital of the VCFs. We use results from existing studies (e.g., Sahlman (1990), Phillips and Kirchoff (1989), and Puri and Zarutskie (2008)) and the restrictions of the model to calibrate the parameters.[4] We estimate management fees to be 16.5% of committed capital. This number is remarkably similar to the management fees of 16.1% and 20.2% reported by Metrick and Yasuda (2009), based on annual management fees of 2% and 2.5% of committed capital respectively. Our estimate is also within the 16–19% range discussed by Gompers and Lerner (1999). We also estimate VCFs' annual rate of return to be 22%, which matches the figures reported by Sahlman (1990) and Kaplan and Schoar (2005).

We also characterize the VC compensation structure. In doing so, our model incorporates features from the most common payment schedules of the industry, such as those described in Metrick and Yasuda (2009). We show that investors receive the exit proceeds from the VCF until they get repaid the full carry basis. After that, both investors and VCs share the VCF's cash flows. In this case, we estimate the carried interest to be 4% of the committed capital for a carry level of 20%, a figure that falls somewhat short of the 7.3% lower bound of Metrick and Yasuda.

Most theoretical papers in the literature focus on the interplay between the VC and the entrepreneur. Some consider the VC as an investor with skills to screen projects (Bernhardt and Krasa (2008)) or an insider that signals to outside investors whether the project is sound (Chan (1983) and Admati and Pfleiderer (1994)). Other studies view the VC as a principal whose role is to ensure that entrepreneurs choose the optimal level of effort (Amist et al. (1990)). In all of these papers, the "investor" is an exogenous association of VCs and financiers. Arguably, this oversimplifies the characterization of the venture capital industry. In the real world, that notion of investor is what is called a "venture capital fund," a much more complex institution. As a result of their setup, those models cannot explain the emergence of VCFs and are unable to characterize the fees charged by VCs.

[4] In particular, we calibrate the model using the following inputs: (1) the probability that a project fails given that it is financed by a VCF, (2) the probability that a project is funded by a VCF, and (3) the probability that a project fails given that it does not get financing from a VCF.

The paper that is closest to ours is Axelson et al. (2008). Those authors consider a model with three agents: investors, venture capitalists, and fly-by-night operators. One of their central results is that venture capital partnerships use a mix of ex-post and ex-ante financing. The compensation scheme the authors derive resembles that of a debt-like contract: for outcomes lower than the amount invested, investors seize everything; while for outcomes above that threshold, investors and VCs receive a fraction of the gains of the project. In the Axelson et al. analysis, VCs are assumed to be fully informed about the quality of projects, while investors and fly-by-night operators are uninformed. Importantly, their model does not explain what determines the management fee charged by VCs. Our framework, in contrast, allows for a more general information structure; for example, we do not impose that either entrepreneurs or VCs are fully informed. Moreover, we focus on the payoffs that VCs and investors derive from the VCF. More generally, by explicitly modeling entrepreneurs, the payoff structures of VCs and investors, and the correlation of information between VCs and entrepreneurs, our analysis complements and extends the existing literature in new directions.

The remainder of the paper is organized as follows. Section 2 describes the model setup. In Section 3, we solve the model and examine its main results. Section 4 performs calibrations studying the main implications of the model. Section 5 concludes the paper. All proofs are in the Appendix.

2 The Model

We set up our model so as match key stylized facts of the venture capital industry. We take that VCs are drawn from a pool of entrepreneurs that have low entrepreneurial capital, which can be thought as human capital, talent, ideas, and inventions. This is in accordance with the Venture Census 2008 (National Venture Capital Association (2008)), which reports that VCs are generally small partnerships composed of former entrepreneurs with industry-specific expertise. Entrepreneurs have projects that require both entrepreneurial capital and outside finance, which is provided by investors. The evidence also shows that a VCF invests in several rounds and that subsequent financing happens only if the previous round of investment is considered successful. To capture these features, we assume that financing takes place in multiple periods.

2.1 Players and Environment

There are three periods $\{0, 1, 2\}$, financing takes place in periods 0 and 1, and there is no discounting. The economy has one investor K and two entrepreneurs $E = \{E_1, E_2\}$. The investor has an amount d that he can lend to entrepreneurs. Each entrepreneur is penniless, but is endowed with entrepreneurial capital and a project. Entrepreneurs hold private information about the quality of their projects. The knowledge and projects of the entrepreneurs are correlated. All agents are risk-neutral.

Entrepreneur $i \in E$ is endowed with entrepreneurial capital $m_i \in \{m_L, m_H\}$, with $m_{E_1} = m_H$

and $m_{E_2} = m_L$. We assume that m_i is common knowledge. Projects can be either good (G) or bad (B). The project of entrepreneur i is denoted by $s_i \in \{G, B\}$, and its outcome by $\pi_{s_i} \in \{\pi_L, \pi_H\}$. We assume $\pi_H > 1$ and $\pi_L = 0$. Bad projects always have an outcome of $\pi_B = \pi_L$.

Projects generate outcomes only after receiving investment and being implemented by an entrepreneur. The investment technology in period 0 dictates that projects require m_H units of entrepreneurial capital and $1 - m_H$ units of external funding, where $0 \leq m_L \leq 1 - d \leq m_H < 1$.[5] We normalize the low entrepreneurial capital to $m_L = 0$. In period 1, the investment technology requires projects to have one unit of outside finance. Entrepreneur i faces opportunity cost $m_i + \overline{u}$, with $\overline{u} > 0$, for implementing a project.

An entrepreneur can be informed or uninformed. If informed, he knows what type of project he holds, otherwise he doesn't know if the project is good or bad. The type of entrepreneur i is given by $\iota_i \in T = \{\{G\}, \{B\}, \{U\}\}$ for $i \in E$, where $\{U\} = \{G, B\}$. The entrepreneur's type is private information. We denote the probability of a good project by $\lambda \in (0, 1)$, the probability of a good outcome by $p \in (0, 1)$, and the probability of being informed about the project's quality by $q \in (0, 1)$. We assume that financing a project that is known to be good is viable $p\pi_H - 1 - u > 0$. To simplify the exposition, we assume $\pi_H - \frac{m_H + \overline{u}}{\lambda p} > 1$. As will become clear in the equilibrium analysis, this assumption implies that a project will be financed in the second period if and only if the investment in period 0 succeeds.

Given that entrepreneur E_2 has a good project, the probability that entrepreneur E_1 has a good project is θ_λ. Conversely, given that entrepreneur E_2 has a bad project, the probability that entrepreneur E_1 has a bad project is γ_λ. The correlation between their knowledge is defined analogously by θ_q and γ_q. Consistency of probabilities require that $k(1 - \theta_k) = (1 - k)(1 - \gamma_k)$ for $k \in \{\lambda, q\}$. For notational purposes, we define $\mu(\iota_i, \iota_j)$ as the prior distribution of types, $\mu(\iota_i)$ as the probability that entrepreneur i is of type ι_i, and $\mu(\iota_i | \iota_j)$ as the associated conditional assessment that entrepreneur i is of type ι_i given that entrepreneur j is of type ι_j.

We will consider the following possibilities: (1) VCs have both *industry expertise* and *entrepreneur expertise*, in which case $(\theta_\lambda, \gamma_\lambda, \theta_q, \gamma_q) = (1, 1, 1, 1)$, and VCs and entrepreneurs have access to the same type of project and share similar information about the project, and (2) VCs have only *industry expertise*, in which case $(\theta_\lambda, \gamma_\lambda, \theta_q, \gamma_q) = (1, 1, q, 1 - q)$, and VCs and entrepreneurs have the same project, but VCs do not know about the entrepreneurs' level of information concerning the project.[6]

[5] Entrepreneurs with entrepreneurial capital of m_L do not have enough resources to be financed in period 0.

[6] Essentially, the state space is $\{G, B\}$ and the type of the entrepreneur represents his information regarding the realized state. We restrict our attention to polar cases for two reasons: (*i*) a more general correlation structure would make the number of parameters to be pinned down by our calibration exercise greater than the number of contraints generated by the model, (*ii*) the results provided by a more general information structure are qualitatively similar.

2.2 Timing, Strategies, and Payoffs

The timing is described in Figure 1. In period 0, Nature chooses the type of each entrepreneur. The wealth endowment is common knowledge. The uninformed investor chooses the entrepreneur to whom he wants to a contract. This initial choice creates two sets of entrepreneurs: financed and non-financed entrepreneurs. The investor decides if he wants to finance the entrepreneur directly or to use the non-financed entrepreneur — now called "venture capitalist" (or VC) — as an intermediary. This type agent assignment is not strictly needed for our results, but naturally matches the stylized fact that venture capitalists typically have entrepreneurial experience in the industry they specialize in. For our purposes, VCs may have information that is correlated with that of entrepreneurs that receive financing.

If he chooses the direct route, the investor sends a contract to the entrepreneur. If the investor chooses the intermediated route, he sends the VC a contract featuring a fixed price (paid up-front) for a report containing information about the project. Upon receiving the report, the investor decides whether to fund the project. Let us detail the events that take place in each period of the model.

- **Period 0**

Nature chooses the type of projects and the knowledge of each entrepreneur. A financing contract specifies a price $R : \{\pi_L, \pi_H\} \to \mathbb{R}^+$ that needs to be paid do the investor, and the ownership over the project in period 1. We assume limited liability such that $R(\pi_s) \leq \pi_s$. Therefore, $R(\pi_L) = 0$ and the relevant choice is regarding the price in the event the project succeeds $R \equiv R(\pi_H)$. The fact that m_i is common knowledge implies that only entrepreneur E_1 will be offered a contract. Since projects do not require entrepreneurial capital in period 1 and entrepreneur E_2 has a lower opportunity cost for implementing a project in that period, the investor will always propose a contract in which he has the ownership over the project of entrepreneur E_1.

The investor decides either to finance the entrepreneur directly or to learn about the venture. The entrepreneur of type ι_{E_2} has belief $\mu(\iota_{E_1}|\iota_{E_2})$ that entrepreneur E_1 is of type ι_{E_1}, and chooses a price $z_{\iota_{E_2}} \in \mathbb{R}^+$ for his information. After observing z and forming belief $\mu_K(\iota_{E_2}|z) \in [0,1]$ that entrepreneur E_2 is of type ι_{E_2}, the investor takes action $e^0_K(z) \in \{0,1\}$, where $e^0_K = 0$ if the investor rejects the offer, and $e^0_K = 1$ if the investor accepts the offer. If the investor chooses uninformed finance, he sends the entrepreneur a contract with price $R_0(z) \in \mathbb{R}^+$. The entrepreneur of type ι_{E_1} holds a belief $\mu_{E_1}(\iota_{E_2}|\iota_{E_1}, z)$ that entrepreneur E_2 is of type ι_{E_2}, and takes action $e^0_{\iota_{E_1}}(R_0) \in \{0,1\}$, where $e^0_{\iota_{E_1}} = 0$ if he rejects the contract and $e^0_{\iota_{E_1}} = 1$ if he accepts.

On the other hand, if the investor chooses informed finance, he signs a contract with the VC (the unfunded entrepreneur E_2). The VC of type ι_{E_2} selects information $\tau_{\iota_{E_2}} \in T$ to reveal. The information $\{G\}$ implies that the VC is informed that the entrepreneur has a good project,

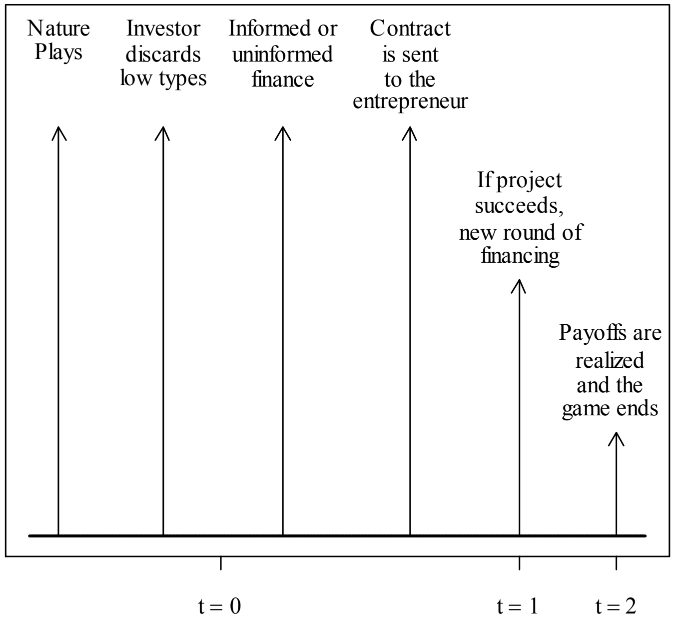

Figure 1: Timing of the Game.

the information $\{B\}$ implies the VC is informed that the entrepreneur has a bad project, and the information $\{U\}$ implies that the VC is uninformed about the quality of the project. Upon receiving a report, the investor has belief $\mu_K(\iota_{E_2}|z,\tau) \in [0,1]$ that the VC is of type ι_{E_2}, and chooses a contract with price $R_1(\tau) \in \mathbb{R}^+$ to be sent to the entrepreneur. The entrepreneur of type ι_{E_1} forms belief $\mu_{E_1}(\iota_{E_2}|\iota_{E_1}, z, \tau)$ that the VC is of type ι_{E_2} and takes action $e^1_{\iota_{E_1}}(R_1) \in \{0,1\}$, where $e^1_{\iota_{E_1}} = 0$ if he refuses to sign it, and $e^1_{\iota_{E_1}} = 1$ if he decides to sign it. If he chooses the former, the game ends.

- **Period 1**

Payments are made according to project outcomes and contracts in place. The payoff of the entrepreneur of type ι_{E_1} is:

$$\begin{aligned} u^0_{\iota_{E_1}} &= \left(1-e^0_K\right)\left[e^0_{\iota_{E_1}}\mathbf{1}_{\{s_{E_1}=G\}}p\left(\pi_H - R_0\right) + \left(1-e^0_{\iota_{E_1}}\right)\left(m_H+\overline{u}\right)\right] + \\ & e^0_K\left[e^1_{\iota_{E_1}}\mathbf{1}_{\{s_{E_1}=G\}}p\left(\pi_H - R_1\right) + \left(1-e^1_{\iota_{E_1}}\right)\left(m_H+\overline{u}\right)\right]. \end{aligned} \quad (1)$$

The payoff of the investor is:

$$\begin{aligned} u^0_K &= \left(1-e^0_K\right)\left[e^0_{\iota_{E_1}}\left(\mathbf{1}_{\{s_{E_1}=G\}}pR_0 + d - (1-m_H)\right) + \left(1-e^0_{\iota_{E_1}}\right)d\right] + \\ & e^0_K\left[e^1_{\iota_{E_1}}\left(\mathbf{1}_{\{s_{E_1}=G\}}pR_1 + d - (1-m_H) - z_{\iota_{E_2}}\right) + \left(1-e^1_{\iota_{E_1}}\right)\left(d - z_{\iota_{E_2}}\right)\right]. \end{aligned} \quad (2)$$

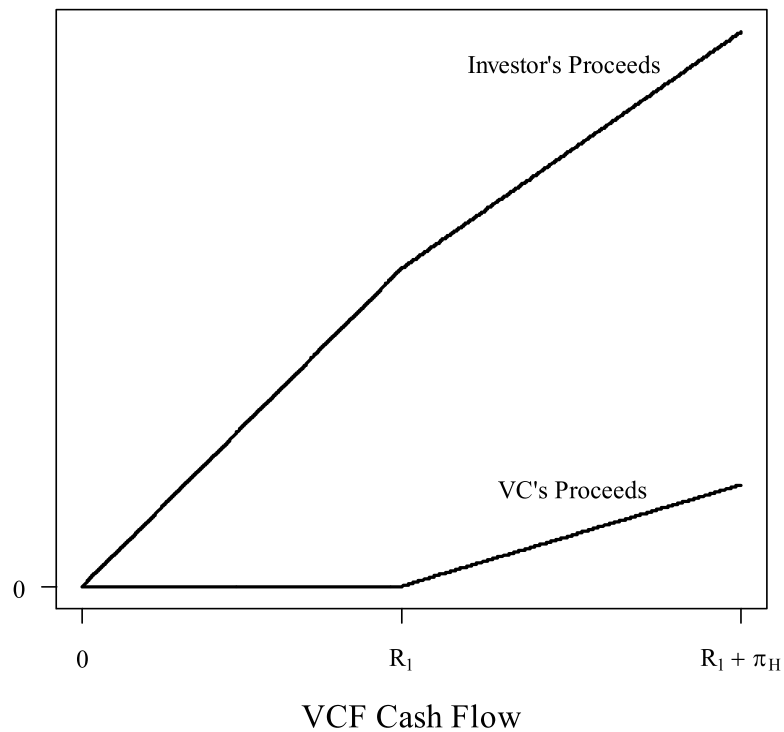

Figure 2: Investor's and VC's Proceeds. The first cash flow of the VCF is the investor's revenue from the investment in period 0, which is given by R_1 and is appropriated by the investor. The second cash flow comes from the outcome of the second round of financing, which is given by π_H and is shared between the VC and the investor.

The payoff of the VC of type ι_{E_2} is:

$$u^0_{\iota_{E_2}} = e^0_K z_{\iota_{E_2}}. \tag{3}$$

Given our assumptions about projects, if the outcome of the project is $\pi_L = 0$, there are insufficient funds for a new financing round and the game ends. If the outcome of the project is π_H, all players believe with probability one that the project is good. Thus, if the investor chose uninformed finance in period 0, he offers a contract with price $R_2 \in \mathbb{R}^+$ to entrepreneur E_2 for implementing the project of entrepreneur E_1. The entrepreneur of type ι_{E_2} chooses $e^2_{\iota_{E_2}}(R_2) \in \{0,1\}$, where $e^2_{\iota_{E_2}} = 0$ if he rejects the contract; otherwise, $e^2_{\iota_{E_2}} = 1$. On the other hand, if the investor chose informed finance, he offers the VC a contract to implement the entrepreneur's project in period 1 with price $R_3 \in \mathbb{R}^+$. The VC of type ι_{E_2} takes action $e^3_{\iota_{E_2}}(R_3) \in \{0,1\}$, where $e^3_{\iota_{E_2}} = 0$ if he rejects the contract, and $e^3_{\iota_{E_2}} = 1$ if he accepts it. If the contract is accepted, investment is made.

• **Period 2**

The payoffs of the second period are realized and the game ends. The payoff of the investor is:

$$u_K^1 = \left(1 - e_K^0\right) e_{\iota_{E_1}}^0 \mathbf{1}_{\left\{\pi_{s_{E_1}} = \pi_H\right\}} e_{\iota_{E_1}}^2 \left(pR_2 - 1\right) + e_K^0 e_{\iota_{E_1}}^1 \mathbf{1}_{\left\{\pi_{s_{E_1}} = \pi_H\right\}} e_{\iota_{E_2}}^3 \left(pR_3 - 1\right). \quad (4)$$

Finally, the payoff of the VC (unfunded entrepreneur) of type ι_{E_2} is:

$$\begin{aligned} u_{\iota_{E_2}}^1 &= \left(1 - e_K^0\right) e_{\iota_{E_1}}^0 \mathbf{1}_{\left\{\pi_{s_{E_1}} = \pi_H\right\}} \left[e_{\iota_{E_2}}^2 p\left(\pi_H - R_2\right) + \left(1 - e_{\iota_{E_2}}^2\right) \overline{u}\right] + \\ & \quad e_K^0 e_{\iota_{E_1}}^1 \mathbf{1}_{\left\{\pi_{s_{E_1}} = \pi_H\right\}} \left[e_{\iota_{E_2}}^3 p\left(\pi_H - R_3\right) + \left(1 - e_{\iota_{E_2}}^3\right) \overline{u}\right]. \end{aligned} \quad (5)$$

Figure 2 describes the investor's and VC's proceeds as a function of the VCF's cash flow. When the investor chooses to offer a contract to the VC, a VCF emerges. The entrepreneur is financed and the investor receives R_1 if the project succeeds. This is the first cash flow of the VCF. In the second round of financing, the VC implements the entrepreneur's project and the outcome in the event of success is given by π_H. This is the VCF's second cash flow and is shared between the VC and the investor, who receive $\frac{\pi_H - R_3}{\pi_H}$ and $\frac{R_3}{\pi_H}$, respectively.

3 Equilibrium

The equilibrium concept we use is that of a Perfect Bayesian Equilibrium (PBE) and we will restrict ourselves to pure strategies. Let $K(z) \subset T$ be the set of types of VC that charge z. The beliefs of the investor and the entrepreneur after observing z are consistent according to Bayes's rule if $\mu_K\left(\iota_{E_2}|z\right) = \frac{\mu\left(\iota_{E_2}\right)}{\sum_{\iota'_{E_2} \in K(z)} \mu\left(\iota'_{E_2}\right)}$ and $\mu_{E_1}\left(\iota_{E_2}|\iota_{E_1}, z\right) = \frac{\mu\left(\iota_{E_2}|\iota_{E_1}\right)}{\sum_{\iota'_{E_2} \in K(z)} \mu\left(\iota'_{E_2}|\iota_{E_1}\right)}$ for $\iota_{E_2} \in K(z)$, and $\mu_K\left(\iota_{E_2}|z\right) = \mu_{E_1}\left(\iota_{E_2}|z\right) = 0$ for $\iota_{E_2} \notin K(z)$.

Analogously, if $K(\tau) \subset T$ is the set of types of VC that report τ, the beliefs of the investor and the entrepreneur after observing τ are *Bayes-consistent* if $\mu_K\left(\iota_{E_2}|z, \tau\right) = \frac{\mu_K\left(\iota_{E_2}|z\right)}{\sum_{\iota'_{E_2} \in K(\tau)} \mu\left(\iota'_{E_2}|z\right)}$ and $\mu_{E_1}\left(\iota_{E_2}|\iota_{E_1}, z, \tau\right) = \frac{\mu_{E_1}\left(\iota_{E_2}|\iota_{E_1}, z\right)}{\sum_{\iota'_{E_2} \in K(\tau)} \mu_{E_1}\left(\iota'_{E_2}|\iota_{E_1}, z\right)}$ for $\iota_{E_2} \in K(\tau)$, and $\mu_K\left(\iota_{E_2}|z, \tau\right) = \mu_{E_1}\left(\iota_{E_2}|\iota_{E_1}, z, \tau\right) = 0$ for $\iota_{E_2} \notin K(\tau)$. Given our assumptions about the correlation of types, the investor's beliefs about the type of the entrepreneur are directly obtained from his beliefs regarding the type of the VC $\mu_K\left(\iota_{E_1}|z\right) = \sum_{\iota'_{E_2} \in K(z)} \mu_K\left(\iota'_{E_2}|z\right) \mu\left(\iota_{E_1}|\iota'_{E_2}\right)$ and $\mu_K\left(\iota_{E_1}|z, \tau\right) = \sum_{\iota'_{E_2} \in K(\tau)} \mu_K\left(\iota'_{E_2}|z, \tau\right) \mu\left(\iota_{E_1}|\iota'_{E_2}\right)$.

Definition 1 *A collection of strategies*

$$\left(\left(e_K^0, R_0, R_1, R_2, R_3\right), \left(e_{\iota_{E_1}}^0, e_{\iota_{E_1}}^1\right), \left(z_{\iota_{E_2}}, \tau_{\iota_{E_2}}, e_{\iota_{E_2}}^2, e_{\iota_{E_2}}^3\right)\right)$$

and beliefs

$$\left(\left(\mu_K\left(\iota_i|z\right), \mu_K\left(\iota_i|z, \tau\right)\right)_{i \in \{E_1, E_2\}}, \left(\mu_{E_1}\left(\iota_{E_2}|\iota_{E_1}, z\right), \mu_{E_1}\left(\iota_{E_2}|\iota_{E_1}, z, \tau\right)\right), \mu\left(\iota_{E_1}|\iota_{E_2}\right)\right)$$

constitutes a (pure strategy) PBE if:

(i) For every history of actions, strategies maximize expected payoffs given beliefs; and

(ii) Beliefs are updated using Bayes' rule whenever possible.

Our first lemma will be useful in order to establish later results. It states that the optimal strategies of the investor and entrepreneur E_2 regarding refinancing are the same under uninformed and informed finance.

Lemma 1 *In any PBE* $R_2 = R_3 = R = \pi_H - \frac{\overline{u}}{p}$, $e^2_{\iota_{E_2}}(R) = e^3_{\iota_{E_2}}(R) = \begin{cases} 1, \text{ if } 0 \leq R \leq \pi_H - \frac{\overline{u}}{p} \\ 0, \text{ if } R > \pi_H - \frac{\overline{u}}{p} \end{cases}$ $\forall \iota_{E_2} \in T \backslash \{B\}$.

Since signing a contract with an entrepreneur of type $\{G\}$ is profitable, the allocation that maximizes total welfare requires good projects being financed with probability λ and bad projects with probability zero. To characterize the outcome of markets under uninformed financing and under VC financing in terms of efficiency, we first need to define equilibria in which VCFs emerge.

Definition 2 *A PBE is a VC-equilibrium if* $e^0_K = 1$ *and* $z_{\iota_{E_2}} > 0 \forall \iota_{E_2} \in T$.

We now proceed to show that there is no separating equilibria with respect to prices; i.e., equilibria where different types of VCs charge different prices for their information. We then show that the investor can restrict attention to charging either a high price or a low price under uninformed finance. The former will be accepted only by informed entrepreneurs with good projects, whereas the latter will be accepted by all entrepreneurs except those informed with bad projects. This will allow the derivation of the expected payoff of the investor given his strategy so that it can be later compared with the expected payoff under informed finance.

Lemma 2 *There is no VC-equilibrium where VCs charge different prices.*

Although this result is consistent with empirical evidence (e.g., Sahlman (1990) and Gompers and Lerner (1999)), it is still viewed in the literature as a puzzle (as discussed by Kaplan and Schoar (2005)). If VCs charged different prices for their information, that would perfectly identify their types. Hence, the investor would get the information he wanted at no cost. As a consequence of this lemma, we will focus out attention to the cases in which $K(z) = T$.

Lemma 3 *Let* $\underline{R_0} = \pi_H - \frac{m_H + \overline{u}}{\lambda p}$, $\overline{R_0} = \pi_H - \frac{m_H + \overline{u}}{p}$, $\overline{R_1} = \pi_H - \frac{m_H + \overline{u}}{p}$, *and* $\underline{R_1}(\tau) = \pi_H - \frac{m_H + \overline{u}}{\mu_{E_1}(G|\{U\}, z, \tau) p}$ *for* $\mu_{E_1}(G|\{U\}, z, \tau) \equiv \sum_{\iota'_{E_2} \in K(\tau)} \mu_{\iota_{E_1}}\left(\iota'_{E_2}|\{U\}, z, \tau\right) \mu\left(G|\iota'_{E_2}, \{U\}\right) > 0$. *In any PBE equilibrium with* $K(z) = T$*:*

(i) $e^k_{\{B\}}(R_k) = 0 \ \forall R_k \in \mathbb{R}^+$,

$$(ii)\ e^k_{\{U\}}(R_k) = \begin{cases} 0,\ if\ \mu_{E_1}(G|\{U\},z,\tau)=0 \\ 1,\ if\ 0 \le R_k \le \underline{R_k}(\tau)\ \ and\ \mu_{E_1}(G|\{U\},z,\tau)>0 \\ 0,\ if\ R > \underline{R_k}(\tau)\ \ and\ \mu_{E_1}(G|\{U\},z,\tau)>0 \end{cases}, \text{ and}$$

$$(iii)\ e^k_{\{G\}}(R_k) = \begin{cases} 1,\ if\ 0 \le R_k \le \overline{R_k} \\ 0,\ if\ R_k > \overline{R_k} \end{cases}\quad for\ k=0,1.$$

Since they contribute with their own resources to the venture, these types of entrepreneurs will reject any contract. The price $\overline{R_k}$, which only informed entrepreneurs with good projects accept, is the highest price an entrepreneur will ever accept. The price $\underline{R_k}$, which is accepted by all entrepreneurs (except the informed entrepreneur with a bad project), is the highest price an uninformed entrepreneur will accept.

Lemma 4 *In any PBE, the investor chooses* $R_0 \in \{\underline{R_0}, \overline{R_0}\}$.

Our setup makes it easy to constrain the investor's pricing strategy to a space in which only two numbers have positive probability mass, making the problem more tractable. The investor need not worry about financing an informed entrepreneur with a bad project. However, if the investor requires a low share of the cash flow as payment, he cannot avoid financing uninformed entrepreneurs with bad projects. On the other hand, if he charges a high price, he will lose good deals from entrepreneurs that are unaware of the quality of their projects, those of type $\{U\}$.

Lemma 5 *There is no VC-equilibrium in which all VCs report the same information.*

This result is also fairly intuitive. If all VCs reported the same information, by consistency of beliefs, the investor would consider the true probability distribution. In this case, the investor would be better off not spending any positive amount on screening services.

The next lemma will be important in deriving the incentives for the VC to report his information accurately. It implies that the investor has enough money to finance the entrepreneur's project in the second period if and only if the investment in period 0 succeeds.

Lemma 6 *Suppose* $\pi_H - \frac{m_H+\overline{u}}{\lambda p} > 1$. *Then in any PBE the condition* $1 \le (d-(1-m_H)+R_k)$ *for* $k=0,1$ *is satisfied.*

We can now calculate the investor's expected payoff given his price strategy $\{R_0, R_1\}$. Under uninformed finance, the investor's expected revenue when he chooses $R_0 = \overline{R_0}$ is:

$$\overline{\Pi} = \lambda q\left[p\left(\pi_H - \frac{m_H+\overline{u}}{p}\right) + p\left(p\pi_H - \overline{u} - 1\right)\right] + d - \lambda q\left(1-m_H\right). \tag{6}$$

On the other hand, if he chooses $\underline{R_0}$, the ex ante expected payoff is:

$$\underline{\Pi} = \lambda p\left[\left(\pi_H - \frac{m_H+\overline{u}}{\lambda p}\right) + \left(p\pi_H - \overline{u} - 1\right)\right] + d - \left(\lambda q + (1-q)\right)\left(1-m_H\right). \tag{7}$$

Note that the investor would always choose $\overline{R_0}$ if $q \to 1$ or $\lambda \to 0$. If the entrepreneur is informed, he will accept a contract if and only if he has a good project. Hence, it is a weakly dominant strategy to charge $\overline{R_0}$. When the entrepreneur has a bad project, the investor can guarantee himself a revenue of zero by choosing $\overline{R_0}$. If he chooses $\underline{R_0}$, his expected revenue will be negative. On the other hand, the investor would always choose $\underline{R_0}$ if $\lambda \to 1$. In this case, we would have $0 < \left(\overline{\Pi} - d\right) = q\left(\underline{\Pi} - d\right) < \left(\underline{\Pi} - d\right)$. Also notice that the higher the values of p, λ, and π_H, the more likely it is for the investor to choose $\underline{R_0}$. The investor's choice of whether to send a contract to the VC is determined by a trade-off between the price that he has to pay and his belief about the accuracy of the VC's information.

Under informed finance, the investor's expected payoff gross of z is:

$$\begin{aligned} \Pi = {} & \theta_q \lambda q \left[pR_1\left(\tau_{\{G\}}\right) + p\left(p\pi_H - \overline{u} - 1\right)\right] + \\ & \left(1-\gamma_q\right)(1-q)\lambda\left[pR_1\left(\tau_{\{U\}}\right) + p\left(p\pi_H - \overline{u} - 1\right)\right] + \\ & \left(1-\theta_q\right)\lambda q e^1_{\{U\}}\left(R_1\left(\tau_{\{G\}}\right)\right)\left[pR_1\left(\tau_{\{G\}}\right) - (1-m_H) + p\left(p\pi_H - \overline{u} - 1\right)\right] + \\ & \gamma_q(1-q)e^1_{\{U\}}\left(R_1\left(\tau_{\{U\}}\right)\right)\left[\lambda pR_1\left(\tau_{\{U\}}\right) - (1-m_H) + \lambda p\left(p\pi_H - \overline{u} - 1\right)\right] - \\ & \left(1-\theta_q\right)(1-\lambda) q e^1_{\{U\}}\left(R_1\left(\tau_{\{B\}}\right)\right)(1-m_H) + d - \lambda q(1-m_H). \end{aligned} \tag{8}$$

The intuition for our results is captured by Figure 3. Suppose $\left(\theta_q, \gamma_q\right) = (1,1)$, $\overline{\Pi} > \underline{\Pi}$, and $\tau_{\{B\}} \neq \tau_{\{U\}} \neq \tau_{\{G\}}$. In this economy, the investor will choose $\overline{R_0}$ if he finances the entrepreneur directly, receiving an expected revenue of $\overline{\Pi}$. However, if he uses VCs as intermediaries and chooses $R_1\left(\tau_{\{G\}}\right) = \overline{R_1}$ and $R_1\left(\tau_{\{U\}}\right) = \underline{R_1}\left(\tau_{\{U\}}\right) = \pi_H - \frac{m_H + \overline{u}}{\lambda p}$, his expected payoff (gross of z) will be:

$$\Pi = \overline{\Pi} + (1-q)\left(\overline{\Pi}(q=0) - d\right) = \underline{\Pi} + q(1-\lambda)\left(m_H + \overline{u}\right). \tag{9}$$

The investor will find it attractive to send a contract to the VC whenever Π is bigger than his expected revenue without screening. The difference is the surplus generated by screening. When the surplus is smaller than the amount of resources left to the investor after financing, the VC will charge the investor the whole surplus, which is denoted by z in the figure. Otherwise he will charge $d - (1 - m_H)$.

The inefficiencies that emerge when investors finance entrepreneurs directly come from the fact that in good times (high λ) some bad projects will be financed and in bad times (low λ) some good projects will not be financed. In good times, bad projects will be financed with probability $(1-q)(1-\lambda)$, and in bad times good projects will be financed with probability $q\lambda$. This prediction is similar to that found in Axelson et al. (2008) and consistent with empirical evidence.

Another interesting implication of our results is that when the market conditions are favorable — large fraction of good projects, high chance of success, and large payoffs — the investor will demand a lower share of the gains from entrepreneurs. The reason is simple: when market conditions are attractive and the investor charges $\overline{R_1}$, he is heavily penalized by not financing uninformed

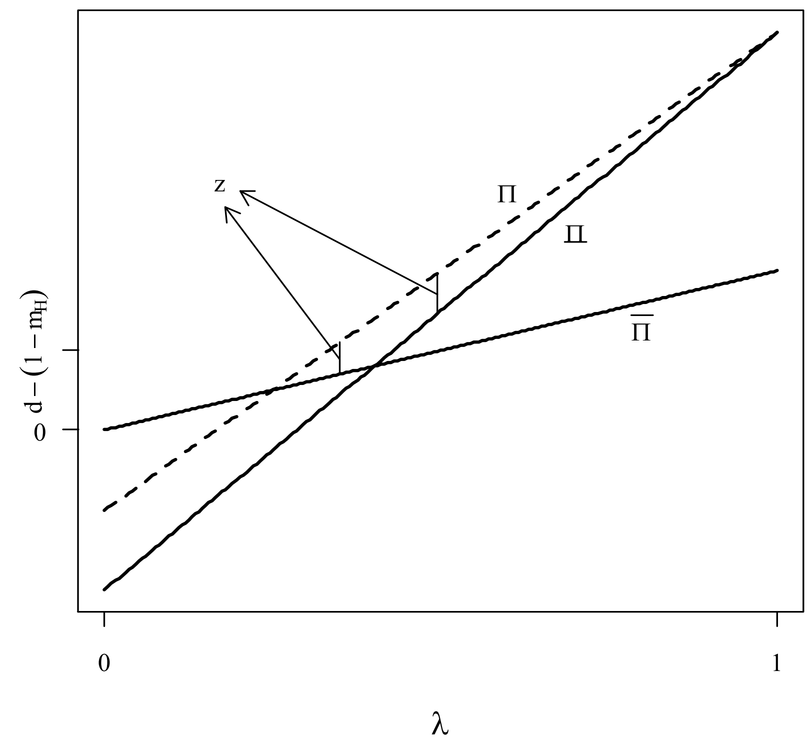

Figure 3: Game Outcomes. $\overline{\Pi}$ is the investor's expected revenue if he charges the entrepreneur a high price, $\underline{\Pi}$ is his expected revenue if he charges a low price, and Π is his expected revenue if he pays VCs for screening. z is the price charged by VCs for screening. λ is the probability that the entrepreneur has a good project and $d - (1 - m_H)$ is the investor's resources after financing a project.

entrepreneurs with good ventures. This cost is reduced when market conditions deteriorate and the probability of financing a uninformed entrepreneur with bad project increases.

Our objective now is to determine when there is a surplus from screening. This will depend on how accurate is the information revealed by the VC. The incentive of the VC to report accurately will depend on his information and on the future gains from the partnership. We proceed examining the case in which VCs have "industry and entrepreneur expertise," and the case in which VCs have only "industry expertise."

3.1 Industry Expertise and Entrepreneur Expertise

This represents the case where the VC can be informed about the project's quality and about the entrepreneur's knowledge about the project's quality. In this subsection, we characterize the VC-equilibria. As a result, the expected surplus from screening will be calculated and the existence of a VC-equilibria will be established. A necessary and sufficient condition for emergence of VCFs is that the expected surplus from financing an entrepreneur that is uninformed about the quality of his venture to be positive.

We characterize VC-equilibria by their types and outcomes. The types of VC-equilibria are: *separating* equilibria, in which $|K(\tau)| = 1 \forall \tau \in T$; and *semi-pooling* equilibria, in which $|K(\tau)| = 2$ for some $\tau \in T$. With slight abuse of notation, we denote τ as the report given by the two types of VC that pool in a semi-pooling equilibrium, and $\tau_{\iota_{E_2}}$ as the report of the separating type ι_{E_2}. Without loss of generality, we will consider the cases $\overline{\Pi} > \underline{\Pi}$, with the set of VC-equilibria denoted by $V\left(\overline{\Pi}\right)$, and $\underline{\Pi} > \overline{\Pi}$, with the set of VC-equilibria denoted by $V\left(\underline{\Pi}\right)$. The outcome of a VC-equilibrium is determined by the investor's action played in equilibrium as a function of VC types $R_1\left(\tau_{\iota_{E_2}}\right)$ and by the price z charged by VCs.

We now establish the first major result of our paper, which is the characterization of VC-equilibria when VCs have both industry expertise and entrepreneur expertise.

Proposition 1 *A VC-equilibrium exists if and only if* $\underline{\Pi}(q=0) - d > 0$. *If a VC-equilibrium exists, then each of the sets* $V\left(\overline{\Pi}\right)$ *and* $V\left(\underline{\Pi}\right)$ *contains three payoff-equivalent types of equilibria in which*

$$z = \begin{cases} \min\left\{d - (1-m_H), (1-q)\left(\underline{\Pi}(q=0) - d\right)\right\} & \text{if } \overline{\Pi} > \underline{\Pi} \\ \min\left\{d - (1-m_H), q(1-\lambda)(m_H + \overline{u})\right\} & \text{if } \underline{\Pi} > \overline{\Pi} \end{cases} :$$

(i) Separating equilibria:

$R_1\left(\tau_{\{G\}}\right) = \overline{R_1}$, $R_1\left(\tau_{\{U\}}\right) = \underline{R_1}\left(\tau_{\{U\}}\right) = \pi_H - \frac{m_H + \overline{u}}{\lambda p}$, *and* $R_1\left(\tau_{\{IB\}}\right) \in \mathbb{R}^+$;

(ii) Semi-pooling equilibria:

(1) $R_1\left(\tau_{\{G\}}\right) = \overline{R_1}$, $R_1(\tau) = \underline{R_1}(\tau) = \pi_H - \frac{m_H + \overline{u}}{\lambda p}$, *and* $R_1(\tau') \in \mathbb{R}^+$ *for* $\tau' \in T \setminus \left\{\tau_{\{G\}}, \tau\right\}$;

(2) $R_1\left(\tau_{\{U\}}\right) = \underline{R_1}\left(\tau_{\{U\}}\right) = \pi_H - \frac{m_H + \overline{u}}{\lambda p}$, $R_1(\tau) = \overline{R_1}$, *and* $R_1(\tau') \in \mathbb{R}^+$ *for* $\tau' \in T \setminus \left\{\tau_{\{U\}}, \tau\right\}$.

The assumption $\underline{\Pi}(q=0) - d > 0$ means that the expected surplus upon financing an entrepreneur who is known to be uninformed about his project is positive. An interesting insight from this proposition is that a truth-telling equilibrium is possible where the investor associates with a VC to form a VCF and VC reports accurately reflect the quality of the projects being financed.

Corollary 1 *If* $\overline{\Pi} > \underline{\Pi}$, *then* z *is non-decreasing in* p, λ, π_H, m_H, d, *and it is non-increasing in* q *and* $\overline{u}$.

Intuitively, if the investor is charging $\overline{R_0}$, then the information becomes more valuable as the probability of good projects increases. This happens because it becomes more likely that uninformed types with good projects will reject a price $\overline{R_0}$. Thus, knowing the true state makes it possible to increase profits. In addition, as the probability of success increases, the loss from not financing an uninformed entrepreneur with a good project also increases, making the information more expensive. The same effect explains the relation regarding the outcome of good projects. On the flip side, when q increases, the possibility of mistakes — i.e., not financing a good project — becomes smaller, making the information less valuable.

Corollary 2 *If $\overline{\Pi} < \underline{\Pi}$, then z is increasing in m_H, non-decreasing in q, $\overline{u}$, d, and non-increasing in λ.*

If the investor charges $\underline{R_0}$, the information becomes more valuable as the probability of being informed increases. This happens because it becomes less likely that an uninformed entrepreneur with a good project will not be financed. At the same time, the potential gains associated with rents extracted from informed entrepreneurs with good projects increase. Therefore, charging $\overline{R_0}$ might increase profits. On the other hand, when λ increases, charging $\underline{R_0}$ reduces the possibility of mistakes (not financing a good project), making the information less valuable.

It is worth noting that these results have welfare implications. When chooses informed finance, bad projects will be financed with probability $(1-\lambda)(1-q)$ and good projects will be financed with probability λ. Since the entrepreneur and the VC have the same knowledge and the same information, a bad project will be financed if and only if the entrepreneur is uninformed with a bad project. Given that a project is bad, it will be financed with probability $(1-q)$, which implies that there is no additional efficiency impact associated with the financing of bad projects. Nonetheless, given that a project is good, it will be financed with probability 1. Therefore, although VCs may not necessarily have a better understanding of the venture (relative to the entrepreneur), they help reduce financing inefficiencies.

3.2 Industry Expertise

We now demonstrate that a VC-equilibrium may emerge even when VCs have more limited information about the types of entrepreneurs. The difference from the last subsection is that the VC is now only potentially informed about the quality of the entrepreneur's project. In other words, the VC might know about the business of the entrepreneur, but he does not know whether the entrepreneur is aware of the quality of his project.

We show that a truth-telling equilibrium is unlikely. The intuition is as follows. Suppose $\overline{\Pi} > \underline{\Pi}$ such that the investor would charge $\overline{R_0}$ under uninformed finance. In this case, uninformed entrepreneurs with good projects would reject contracts. In a separating equilibrium under informed finance, uninformed entrepreneurs with good projects learn about the quality of their projects. This allows investors to demand $\overline{R_1}$ from these entrepreneurs and increase their expected payoffs. Since the signal of the VC of type $\{U\}$ is uninformative, the investor also charges $\overline{R_1}$ upon receiving a report from a VC of type $\{U\}$ (since this was optimal under uninformed finance). For this equilibrium to be sustained, the investor must also charge a price that is sufficiently large after observing a report from a VC of type $\{B\}$ (otherwise the VC of type $\{U\}$ would deviate from his report). Now suppose there is a VC-equilibrium in which the VC of type $\{U\}$ pools with the VC of type $\{G\}$. Under this equilibrium, it must be the case that the investor charges $\underline{R_1}(\tau)$ upon receiving report τ from either the VC of type $\{G\}$ or the VC of type $\{U\}$. This follows from the observation that, if the investor charged $\overline{R_1}$, only entrepreneurs of type $\{G\}$ would accept the contract, giving the investor the same expected payoff as under uninformed finance. The difference from the separating equilibrium is that, while the VC of type $\{G\}$ has the same expected payoff, the VC of type $\{U\}$ receives a higher expected carried interest. Therefore, one should expect the VC of type $\{U\}$ to try to convince the investor that his type is in $\{\{G\},\{U\}\}$. If he announces that his type is in $\{\{G\},\{U\}\}$, the investor has no reason not to believe it since the equilibrium strategy of the VC of type $\{B\}$ gives him a payoff that is at least as good as the best payoff he receives if the announcement is believed (he receives 0 in both cases). At the same time, the VC of type $\{G\}$ is indifferent and could well be the author of the announcement.

We now establish the second major result of our paper, which is the characterization of equilibria when VCs have only industry expertise.

Proposition 2 *(i) If $\overline{\Pi} > \underline{\Pi}$, then a VC-equilibrium exists. The set $V\left(\overline{\Pi}\right)$, contains two payoff-equivalent types of equilibria in which $z = \min\left\{d - (1 - m_H), (1-q)\left(\overline{\Pi} - d\right)\right\}$:*

(1) Separating equilibria:

$R_1\left(\tau_{\{G\}}\right) = \underline{R_1}\left(\tau_{\{G\}}\right) = \overline{R_1}$, $R_1\left(\tau_{\{U\}}\right) = \overline{R_1}$, $R_1\left(\tau_{\{B\}}\right) \in \left(\underline{R_1}\left(\tau_{\{U\}}\right), +\infty\right)$ *for* $\underline{R_1}\left(\tau_{\{U\}}\right) = \pi_H - \frac{m_H + \overline{u}}{\lambda p}$,

(2) Semi-pooling equilibria:

$R_1\left(\tau_{\{G\}}\right) = \underline{R_1}\left(\tau_{\{G\}}\right) = \overline{R_1}$, $R_1(\tau) = \overline{R_1}$, $R_1(\tau') \in \left(\underline{R_1}(\tau), +\infty\right)$ *for* $\tau' \in T \backslash \left\{\tau_{\{G\}}, \tau\right\}$ *and* $\underline{R_1}(\tau) = \pi_H - \left(\frac{1-\lambda q}{1-q}\right)\frac{m_H + \overline{u}}{\lambda p}$.

(ii) The set $V\left(\overline{\Pi}\right)$ contains semi-pooling equilibria in which $K(\tau) = \{\{IG\},\{U\}\}$ if and only if

$$(1-q)\left(\underline{\Pi}(q=0) - d\right) - (1-q)\frac{[q(1-\lambda)]^2}{1 - q(1-\lambda)}(m_H + \overline{u}) \geq 0:$$

$R_1\left(\tau_{\{B\}}\right) \in \mathbb{R}^+$, $R_1(\tau) = \underline{R_1}(\tau) = \pi_H - [1 - q(1-\lambda)]\frac{m_H + \overline{u}}{\lambda p}$, $R_1(\tau') \in \mathbb{R}^+$ *for* $\tau' \in T \backslash \left\{\tau_{\{B\}}, \tau\right\}$, *and* $z = \min\left\{d - (1 - m_H), (1-q)\left(\underline{\Pi} - d\right)\right\}$,

(iii) Semi-pooling equilibria in which $K(\tau) = \{\{G\},\{B\}\}$ do not exist.

As the proposition states, we have the possibility of two equilibria with different outcomes. We will use the refinement proposed by Matthews et al. (1991) for cheap-talk games to find a unique outcome prediction among the equilibria in $V\left(\overline{\Pi}\right)$. We first state the payoffs of the VC and the investor of the cheap-talk game that starts when $e_K = 1$. The investor's expected payoff given his belief upon receiving report τ is:

$$u_K(R_1, \tau) \equiv \sum_{\iota_{E_1} \in T} \mu_K\left(\iota_{E_1} | z, \tau\right) \begin{bmatrix} e^1_{\iota_{E_1}}\left(R_1(\tau)\right)\left(\mu\left(G|\iota_{E_1}\right) p R_1(\tau) + d - (1 - m_H) - z\right) + \\ \left(1 - e^1_{\iota_{E_1}}\left(R_1(\tau)\right)\right)(d - z) + e^1_{\iota_{E_1}} \mu\left(G|\iota_{E_1}\right) p \left(p\pi_H - \overline{u} - 1\right) \end{bmatrix}. \tag{10}$$

The expected payoff of the VC of type ι_{E_2} is:

$$u_{E_2}\left(R_1,\tau_{\iota_{E_2}},\iota_{E_2}\right) \equiv \sum_{\iota_{E_1}\in T} e^1_{\iota_{E_1}}\left(R_1\left(\tau_{\iota_{E_2}}\right)\right)\mu\left(\iota_{E_1}|\iota_{E_2}\right)\mu\left(G|\iota_{E_1},\iota_{E_2}\right)p\overline{u}. \tag{11}$$

It is clear that the VC of type $\{U\}$ prefers those equilibria in (ii) to those in (i). To see this note that his payoff in (i) is $u_{E_2}\left(R_1,\tau_{\{U\}},\{U\}\right)=\lambda qp\overline{u}$, while his payoff in (ii) is $u_{E_2}\left(R_1,\tau_{\{U\}},\{U\}\right)=\lambda qp\overline{u}+\lambda(1-q)p\overline{u}=\lambda p\overline{u}$. However, VCs of type $\{G\}$ and $\{B\}$ are indifferent between equilibria played in (i) and equilibria played in (ii) since in each of them they receive $u_{E_2}\left(R_1,\tau_{\{IG\}},\{G\}\right)=qp\overline{u}+(1-q)\lambda p\overline{u}$ and $u_{E_2}\left(R_1,\tau_{\{B\}},\{B\}\right)=0$ respectively.

The idea behind the "strongly announcement-proof" criterion proposed in Matthews et al. is simple. Consider the equilibria in (i) and let P be a non-empty collection of non-empty and disjoint subsets of T. Suppose that $D=\{\{G\},\{U\}\}\in P$ and the VC of type $\{U\}$ announces: (1) his type is in $D=\{\{G\},\{U\}\}$, (2) if his type were in another set in P he would have announced that, and (3) if his type were not in P he would have played his equilibrium strategy instead of making this announcement. If the investor and the entrepreneur believe this announcement, they update their beliefs such that:

$$\widehat{\mu}_K\left(\iota_{E_2}|z,D\right) = \begin{cases}\dfrac{\mu_K\left(\iota_{E_2}|z\right)}{\sum\limits_{\iota'_{E_2}\in D}\mu\left(\iota'_{E_2}|z\right)} \text{ if } \iota_{E_2}\in D \\ 0 \text{ if } \iota_{E_2}\notin D\end{cases}, \tag{12}$$

$$\widehat{\mu}_{E_1}\left(\iota_{E_2}|\iota_{E_1},z,D\right) = \begin{cases}\dfrac{\mu_{E_1}\left(\iota_{E_2}|\iota_{E_1},z\right)}{\sum\limits_{\iota'_{E_2}\in D}\mu\left(\iota'_{E_2}|\iota_{E_1},z\right)} \text{ if } \iota_{E_2}\in D \\ 0 \text{ if } \iota_{E_2}\notin D\end{cases}. \tag{13}$$

Formally, an announcement is a pair $\langle D,P\rangle$ where P is an announcement strategy and $D\in P$. The set of deviant types is $T(P)=\{\iota_{E_2}\in T:\exists D\in P:\iota_{E_2}\in D\ \}$. Let $u_{E_2}\left(R_1,\tau_{\iota_{E_2}},\iota_{E_2}\right)$ be the payoff of the VC of type ι_{E_2} in some equilibrium in $V\left(\overline{\Pi}\right)$, $\underline{u}_{E_2}\left(R_1,D,\iota_{E_2}\right)$ be the minimum expected payoff that VC of type ι_{E_2} can receive in an equilibrium if announcement $\langle D,P\rangle$ is believed, and let $\overline{u}_{E_2}\left(R_1,D,\iota_{E_2}\right)$ be the maximum payoff the VC of type ι_{E_2} can receive if announcement $\langle D,P\rangle$ is believed.

Definition 3 *An announcement strategy P and the corresponding announcements $\langle D,P\rangle$ are credible relative to an equilibrium in $V\left(\overline{\Pi}\right)$ if:*

(i) $\underline{u}_{E_2}\left(R_1,D,\iota_{E_2}\right)\geq u_{E_2}\left(R_1,\tau_{\iota_{E_2}},\iota_{E_2}\right)$ for all $D\in P$ and $\iota_{E_2}\in D$ with at least one strict inequality;

(ii) $\overline{u}_{E_2}\left(R_1,D,\iota_{E_2}\right)\leq u_{E_2}\left(R_1,\tau_{\iota_{E_2}},\iota_{E_2}\right)$ for all $\iota_{E_2}\in T/T(P)$

(iii) $\underline{u}_{E_2}\left(R_1,D,\iota_{E_2}\right)\geq\underline{u}_{E_2}\left(R_1,\overline{D},\iota_{E_2}\right)$ for all $\overline{D},D\in P$ and $\iota_{E_2}\in D$.

If no announcement is weakly credible, then this equilibrium and its outcome are strongly announcement-proof.

Given the formal criterion stated in this definition, we are now able to reject all but the equilibria in (ii) of Proposition 2. This results is notable since we have a unique prediction outcome which allows us to derive comparative statics regarding the management fee charged by VCs. In addition, this result suggests that a truth-telling VC-equilibrium is unlikely.

Proposition 3 *The equilibria in (i) of Proposition 2 are not strongly announcement-proof. The equilibria in (ii) of Proposition 2 are strongly announcement proof.*

This is the third central result of our paper. It allows us to derive a set of comparative statics results. In particular, the model has a very clear prediction about the relationship between management fees and private equity activity. Investments in the VC industry are positively correlated with the fixed compensation received by VCs, which makes management fees pro-cyclical.

Corollary 3 *For equilibria in (ii) of Proposition 2, z is increasing in m_H, non-decreasing in p, λ, π_H, d, and non-increasing in $\overline{u}$. Moreover, there exists a $\lambda^* \in (0,1)$ such that z non-increasing in q for $\lambda > \lambda^*$ and non-decreasing in q for $\lambda < \lambda^*$.*

The main difference between this result and the one obtained in the previous subsection relates to q. When q increases, report τ is more informative since it is more likely to come from the VC of type $\{G\}$ than from the VC of type $\{U\}$. Uninformed entrepreneurs would believe with higher probability that they hold a good project, which would allow the investor to charge a higher price. However, when λ is reasonably high, increases in q greatly reduce the potential loss from not financing an uninformed entrepreneur with a good project. At the same time, for low levels of λ, increases in q not only make report τ more informative, but also increase the potential loss from not financing uninformed entrepreneurs with good projects. Therefore, the information becomes more valuable.

We now establish the last major result of the paper, characterizing equilibria when VCs have only industry expertise and $\underline{\Pi} > \overline{\Pi}$.

Proposition 4 *(i) If $\underline{\Pi} > \overline{\Pi}$, then a VC-equilibrium exists. The set $V(\underline{\Pi})$ contains separating equilibria:*

$R_1\left(\tau_{\{G\}}\right) = \underline{R_1}\left(\tau_{\{G\}}\right) = \overline{R_1}$, $R_1\left(\tau_{\{U\}}\right) = \underline{R_1}\left(\tau_{\{U\}}\right) = \pi_H - \frac{m_H+\overline{u}}{\lambda p}$, $R_1\left(\tau_{\{B\}}\right) \in \mathbb{R}^+$, and $z = \min\left\{d-(1-m_H), q(1-\lambda)\left[(1-q)(1-m_H)+m_H+\overline{u}\right]\right\}$

(ii) Semi-pooling equilibria:

The set $V(\underline{\Pi})$ contains semi-pooling equilibria in which $K(\tau) = \{\{G\},\{U\}\}$ if and only if

$$(1-q)\left(\underline{\Pi}(q=0)-d\right)-(1-q)\frac{\left[q(1-\lambda)\right]^2}{1-q(1-\lambda)}(m_H+\overline{u}) \geq 0:$$

$R_1\left(\tau_{\{B\}}\right) \in \mathbb{R}^+$, $R_1(\tau) = \underline{R_1}(\tau) = \pi_H - [1-q(1-\lambda)]\frac{m_H+\overline{u}}{\lambda p}$, $R_1(\tau') \in \mathbb{R}^+$ for $\tau' \in T\backslash\left\{\tau_{\{B\}},\tau\right\}$, and $z = \min\left\{d-(1-m_H), q(1-\lambda)\left[(1-q)(1-m_H)+m_H+\overline{u}\right]\right\}$.

(iii) Semi-pooling equilibria in which $K(\tau) = \{\{G\}, \{B\}\}$ and $K(\tau) = \{\{U\}, \{B\}\}$ do not exist.

Corollary 4 *z increasing in m_H, non-decreasing in $\overline{u}$, and non-increasing in λ.*

In this variation, bad projects will be financed with probability $(1-\lambda)(1-q)^2$ and good projects with probability λ. Without VCs, bad projects are financed with probability $(1-q)(1-\lambda)$ during booms, and good projects are financed with probability $q\lambda$ during busts. VCs reduce the probability that a bad project is financed to only a fraction $(1-q)$ of the non-VC-equilibrium. At the same time, the odds that a good project gets funding in bad states are multiplied by $\frac{1}{q}$. Notably, although VCs do not report truthfully when they are uninformed about the venture, they reduce inefficiencies even further. What drives this result is the fact that the VC may know about the quality of the venture even if the entrepreneur is uninformed.

4 Model Calibration

We calibrate our model for the case in which VCs have industry expertise. We focus on this case because it requires the least amount of knowledge by the VCs and yet it offers enough conditions to identify the model parameters. Our numbers come largely from the study of Sahlman (1990) on the venture capital industry. An individual investment is characterized by the funding given to a single firm throughout the financing cycle and by the length of the financing cycle. The model's VCF invests in a single project. We take that the representative real-world counterpart of that project is the average start-up company financed by VCs. The average life of an investment in Sahlman (1990) is 5 years and the results derived here should be interpreted with that time horizon in mind.

In the model, the price charged by the VC is independent of the success of the venture that is financed. The same is true regarding the management fees that VCs charge in the real world. In addition, VCs usually get 20% of the profits in case of success. The counterpart in the model is the VC's reservation utility for carrying out the project. The VC receives that amount only if the investment does not fail in period 0.

Our first step is to calibrate π_H. Sahlman reports that around 16% of investments are responsible for 75% of the ending value of the portfolio. Moreover, about 34% of the ventures sponsored by the VCs fail. The remaining 50% of the investments account for 25% of the total ending value. He also finds that the ending value of investments is 4.3 times the original cost.

One can represent the numbers in Sahlman assuming that the ending value of the portfolio is as a random variable that takes values 0, 2.15, and 20.156 with probabilities 0.34, 0.50, and 0.16 respectively. We can represent this by points (x, y) in $\mathbb{R}^2$ such that $(x, y) \in \Sigma = \{(0.16, 20.156), (0.34, 0), (0.50, 2.15)\}$. Let us define $\Gamma = \sum_{\{x:(x,y)\in\Sigma\}} |f(x) - y|$. In our model, an investment can only take the values π_H and π_L. Therefore, we want to calibrate π_H and π_L in order to concisely approximate the set Σ. One way of doing it is by using a step function with two steps. We define an optimal step function as one that minimizes Γ.[7] An optimal two-step function approximation $f : [0,1] \to \mathbb{R}$ that minimizes Γ is given by:

$$f(x) = \begin{cases} 20.156, \text{ for } x \in [0, 0.34) \\ 0, \text{ for } x \in [0.34, 1] \end{cases}.$$

We want an approximation such that the average ending value of investments is equal to 4.3. Accordingly, we need a two-step function f' that minimizes Γ subject to $\sum_{\{x:(x,y)\in\Sigma\}} xf'(x) = 4.3$. It is straightforward to see that the following function satisfies the requirement:

$$f'(x) = \begin{cases} 26.875, \text{ for } x \in [0, 0.34) \\ 0, \text{ for } x \in [0.34, 1] \end{cases}.$$

We can model the ending value of a portfolio of projects as a Bernoulli random variable which takes values $\pi_H = 27$ in case of success and $\pi_L = 0$ otherwise. This gives us the best two-step function approximation to the actual ending value distribution (subject to the constraint that average implied by the model matches the data).

We continue our exercise using additional information from the VC industry. In particular, we note that in 88% of the funds surveyed by Sahlman, VCs are entitled to 20% of the realized gains. Since the average expected net gain from an investment is 3.3 (= 4.3 − 1), we set $\overline{u} = 0.66$. The average share of the ending portfolio held by the founders of the venture (entrepreneurs) is roughly 30%. We thus set $m_H = 0.3$.

Since 34% of the ventures sponsored by VCs might be expected to fail, we have an estimate of the probability that an investment fails given that it is financed by VCs. The equilibrium of our model implies that a bad project will be financed with probability $(1-\lambda)(1-q)^2$ and a good project will be financed with probability λ. Thus, the following condition must be satisfied:

$$0.34 = \Pr(\text{failure}|\text{financed by VCFs}) = \frac{(1-\lambda)(1-q)^2 + \lambda(1-p)}{(1-\lambda)(1-q)^2 + \lambda}. \tag{14}$$

From Berlin (1998), we take that the probability that a VC funds a received project is 10%. In our model, the probability that a project will be financed by the VCF is $(1-\lambda)(1-q)^2 + \lambda$. As a result, we have the following condition:

$$0.1 = \Pr(\text{funding}) = (1-\lambda)(1-q)^2 + \lambda. \tag{15}$$

Our next condition comes from the probability of failure given that all projects are financed. One of the main distinctions between VC-financed and non-VC-financed firms is that the former typically have low cash flows and do not have tangible assets to offer as collateral. Puri and Zarutskie (2008)

[7] Another way of fitting a step function to a point set is by minimizing the maximum vertical difference (see Fournier and Vigneron (2008)). Our conclusions are similar if we use this alternative approach.

Table 1. Calibrated Parameters of the Model

π_H is the return of a good project in the good state, q is the probability that the entrepreneur is informed, p is the probability that a good project succeeds, λ is the probability that the entrepreneur has a good project, $\overline{u}$ is the entrepreneur's reservation utility, m_H is the high-type entrepreneurial capital, and d is the investor's amount of resources. See text for details of the parameter setting process.

π_H	q	p	λ	$\overline{u}$	m_H	d
27	0.911	0.711	0.093	0.66	0.30	1

show that 47% of firms financed by VCs have zero cash revenue in their first year, compared to only 6% of firms with other sources of financing. They also report evidence that most of the difference between failure rates of VC-financed and non-VC-financed firms is due to successful selection of good projects by VCs. In other words, firms that seek VC financing are drawn from the general distribution of start-up firms in the economy, but VCs seem to add value by way of their selection process. Phillips and Kirchoff (1989), Puri and Zarutskie (2008), and Bernhardt and Krasa (2008) estimate the failure rate of all start-up firms, firms financed outside the VC industry, and all firms that seek finance from VCs to be, respectively, 60% , 62%, and 57%. We establish the following condition:

$$0.62 = \Pr\left(\text{failure}|\text{all financed}\right) = \frac{(1-\lambda)(1-q) + \lambda(1-q)(1-p) + \lambda q(1-p)}{(1-\lambda)(1-q) + \lambda(1-q) + \lambda q}. \tag{16}$$

Using conditions (7), (8), and (9) we can solve for q, λ, and p:

$$\lambda = 0.093,\ p = 0.711,\ q = 0.911. \tag{17}$$

These conditions imply an environment where the probability of good projects is low. However, given that the project is of good quality, its probability of success is high. This result highlights the consistency of our model with the VC industry and provides insights into the economic role of VCs. In essence, VCs are agents that can screen out bad projects in an environment where good projects are scarce, adding value to investors.

Lastly, we normalize the investor's money endowment to one; i.e., $d = 1$. We summarize the calibration of the parameters in Table 1.

We can now compute the endogenous variables of the model:

$$\overline{\Pi} = 2.538,$$

$$\underline{\Pi} = 1.858,$$

$$\overline{R_1} = \left(\pi_H - \frac{m_H + \overline{u}}{p}\right) = 25.650,$$

$$\underline{R_1} = \pi_H - \left[1 - q(1-\lambda)\right]\frac{m_H + \overline{u}}{\lambda p} = 24.474.$$

These estimates suggest that the investor would have charged 25.603 if he did not have the option to buy information from the VC. In other words, if the project succeeded, the entrepreneur would have to give the investor 25.603 from the realized gain of 26.875. However, Propositions 2 and 3 say that the investor will buy the services from the VC at a price determined by:

$$\Pi = \overline{\Pi} + (1-q)\left(\underline{\Pi} - d\right) = 2.703,$$
$$z^* = \min\left\{1 - (1 - m_H), \Pi - \overline{\Pi}\right\} = \min\{0.3, 0.165\} = 0.165.$$

We note that these estimates match the real-world data quite well. The committed capital in our model is given by $d = 1$, which is the amount of resources the investor is willing to commit to the VCF at time 0. Accordingly, the estimations imply that the management fee charged by VCs is equal to 16.5% of committed capital. This is consistent with the numbers estimated by Metrick and Yasuda (2009) for VCFs with annual management fees of 2% and 2.5%, which are respectively 16.1% and 20.2%. This estimate also falls in the management fee range of 16–19% that is reported by Gompers and Lerner (1999). Our estimated return of a VCF (net of fees) over its life is 2.703. The implied effective annual rate of return, in a five-year horizon, is 22%.[8] As it turns out, this number is virtually the same as those reported by Sahlman (1990) and Kaplan and Schoar (2005). Finally, the expected carried interest received by the VC is given by

$$(1-q)\lambda p\overline{u} + \lambda q\left(qp\overline{u} + (1-q)\lambda p\overline{u}\right) = 0.0404.$$

This estimate falls somewhat short of the 0.073–0.083 range estimated by Metrick and Yasuda (2009) for VCFs with carry level of 20%.

To sum up, our model calibration matches key elements of the VC industry, such as expected returns and management fees. We estimate management fees to be 16.5% of committed capital and an annual rate of return of 22% for the industry. Notably, our model is consistent with the fact that the industry deals with risky projects. Only few projects have positive net present value, which makes the information and experience of VCs all the more valuable to investors.

5 Concluding Remarks

We investigate the emergence and efficiency of venture capital partnerships. We develop a model in which an uniformed investor offers a debt contract and decides whether to screen an entrepreneur before financing. Financing takes place in two periods. Investment in the first period requires resources from both the investor and the entrepreneur. Entrepreneurs are heterogeneous with respect to wealth, information, and project quality. Venture capitalists (VCs) provide information for screening activity at some price. The association created when the investor uses the services (i.e., buys information) from the VC gives rise to the venture capital fund (VCF).

We derive equilibrium conditions in which the investor always pay VCs in order to carry out screening (*VC-equilibrium*). In general, a VCF will emerge provided that it is worth financing an

[8] The effective rate of return r is given by $2.703 = (1+r)^5$.

entrepreneur that is know to be uninformed about the quality of the venture. The willingness of the investor to buy information from VCs will depend on his expected return when he does not buy information and on his beliefs about the accuracy of the screening. The precision of screening will depend on the information of VCs and on the expected gains upon forming a VCF.

Uninformed finance allows for inefficient outcomes as good projects are not financed in bad times and bad projects are financed in good times. When VC signals about the quality of projects are highly correlated with that of entrepreneurs, reports to investors closely reflect the quality of the screening they provide. VCs always increase efficiency in that a greater proportion of good projects is financed in bad times. When the signals of VCs are not highly correlated with those of entrepreneurs, VCs might provide inaccurate reports to investors about investments opportunities. Even in this case, however, reports are precise enough so as to adjust beliefs of investors and entrepreneurs about projects. A larger proportion of good projects is financed in good times and a lower proportion of bad projects is financed in bad times — inefficiency is further reduced.

Finally, we use previous studies to calibrate the model. We find estimates for the management fees charged by VCs and industry returns that are quite consistent with empirical evidence. While there is much work to do on the economics of venture capital financing, the analysis of this paper helps reconcile a number of features of the VC industry within a standard contract theory framework.

Appendix

Proof of Lemma 1. The expected payoff of entrepreneur E_1 under uninformed finance at the time of refinancing is $e^2_{\iota_{E_2}} p(\pi_H - R_2) + \left(1 - e^2_{\iota_{E_2}}\right)\overline{u}$. Therefore, $e^2_{\iota_{E_2}} = 1$ if and only if $p(\pi_H - R_2) \geq \overline{u} \iff \pi_H - \frac{\overline{u}}{p} \geq R_2$. Analogously, the expected payoff of the VC at the time of refinancing under informed finance is $e^3_{\iota_{E_2}} p(\pi_H - R_3) + \left(1 - e^3_{\iota_{E_2}}\right)\overline{u}$. Therefore $e^3_{\iota_{E_2}} = 1$ if and only if $\pi_H - \frac{\overline{u}}{p} \geq R_3$.

The payoff of the investor under uninformed finance is $e^2_{\iota_{E_1}}(pR_2 - 1)$, which is equal to 0 if $R_2 > \pi_H$ and equal to $pR_2 - 1$ for $R_2 \leq \pi_H - \frac{\overline{u}}{p}$. The optimal strategy is $R_2 = \pi_H - \frac{\overline{u}}{p}$, which gives a payoff of $p\pi_H - \overline{u} - 1 > 0$. The investor's payoff under informed finance is $e^3_{\iota_{E_2}}(pR_3 - 1)$, which is equal to 0 if $R_3 > \pi_H - \frac{\overline{u}}{p}$ and $pR_3 - 1$ if otherwise. It is optimal for the investor to choose $R_3 = \pi_H - \frac{\overline{u}}{p}$, which gives him a payoff of $p\pi_H - \overline{u} - 1 > 0$. ■

Proof of Lemma 2. Suppose there is a VC-equilibrium each VC charges a different price $z_{\iota_{E_2}}$. We will show that the best strategy for the investor is to choose $e^0_K = 0$, which leads to a contradiction. Note that, by consistency of beliefs, we have $\mu_K\left(\iota_{E_2}|z_{\iota_{E_2}}\right) = \mu_K\left(\iota_{E_2}|z_{\iota_{E_2}}, \tau_{\iota_{E_2}}\right) = 1$ and $\mu_{E_1}\left(\iota_{E_2}|\iota_{E_1}, z_{\iota_{E_2}}\right) = \mu_{E_1}\left(\iota_{E_2}|\iota_{E_1}, z_{\iota_{E_2}}, \tau_{\iota_{E_2}}\right) = 1$. Using this along with the result of lemma 1 will allow us to compare the investor's payoff when $e^0_K = 0$ to that when $e^0_K = 1$. The entrepreneur's belief that his project is of type G is $\mu(G|\iota_{E_1}, \iota_{E_2})$. Without loss of generality, assume $\mu(G|\iota_{E_1}, \iota_{E_2}) > 0$.

Case 1 ($e^0_K = 0$): We can write the entrepreneur's expected payoff by:

$$e^0_{\iota_{E_1}} \mu(G|\iota_{E_1}, \iota_{E_2}) p(\pi_H - R_0) + \left(1 - e^0_{\iota_{E_1}}\right)(m_H + \overline{u}).$$

Therefore, she will choose $e^0_{\iota_{E_1}} = 1$ if and only if:

$$\mu(G|\iota_{E_1}, \iota_{E_2}) p(\pi_H - R_0) \geq m_H + \overline{u}$$

Since the investor knows that type of the VC, his belief that the project is good is $\mu(G|\iota_{E_2})$. The expected payoff of the investor is:

$$e^0_{\iota_{E_1}}(\mu(G|\iota_{E_2}) pR_0 + d - (1 - m_H)) + \left(1 - e^0_{\iota_{E_1}}\right) d + e^0_{\iota_{E_1}} p\mu(G|\iota_{E_2})(p\pi_H - \overline{u} - 1).$$

Thus, if he sets $R_0 \leq \pi_H - \frac{m_H + \overline{u}}{\mu(G|\iota_{E_1}, \iota_{E_2}) p}$ his expected payoff is

$$\mu(G|\iota_{E_2}) pR_0 + d - (1 - m_H) + p\mu(G|\iota_{E_2})(p\pi_H - \overline{u} - 1), \tag{A.1}$$

and if he sets otherwise, d. He will choose $R_0 = \pi_H - \frac{m_H + \overline{u}}{\mu(G|\iota_{E_1}, \iota_{E_2}) p}$ if and only if:

$$\mu(G|\iota_{E_2}) p\pi_H - (m_H + \overline{u}) \frac{\mu(G|\iota_{E_2})}{\mu(G|\iota_{E_1}, \iota_{E_2})} - (1 - m_H) + p\mu(G|\iota_{E_2})(p\pi_H - \overline{u} - 1) \geq 0. \tag{A.2}$$

Case 2 ($e^0_K = 1$): The entrepreneur's expected payoff is:

$$e^1_{\iota_{E_1}} \mu(G|\iota_{E_1}, \iota_{E_2}) p(\pi_H - R_1) + \left(1 - e^1_{\iota_{E_1}}\right)(m_H + \overline{u}).$$

This implies that the entrepreneur will choose $e^1_{\iota_{E_1}}$ if and only if:

$$\mu\left(G|\iota_{E_1},\iota_{E_2}\right)p\left(\pi_H-R_1\right)\geq m_H+\overline{u}$$

The investor's expected payoff is:

$$e^1_{\iota_{E_1}}\left(\mu\left(G|\iota_{E_2}\right)pR_1+d-(1-m_H)-z_{\iota_{E_2}}\right)+\left(1-e^1_{\iota_{E_1}}\right)\left(d-z_{\iota_{E_2}}\right)+e^1_{\iota_{E_1}}p\mu\left(G|\iota_{E_2}\right)\left(p\pi_H-\overline{u}-1\right).$$

If he chooses $R_1\leq\pi_H-\frac{m_H+\overline{u}}{\mu\left(G|\iota_{E_1},\iota_{E_2}\right)p}$ his expected payoff is

$$\mu\left(G|\iota_{E_2}\right)pR_1+d-(1-m_H)-z_{\iota_{E_2}}+p\mu\left(G|\iota_{E_2}\right)\left(p\pi_H-\overline{u}-1\right), \tag{A.3}$$

and if he sets otherwise, $d-z_{\iota_{E_2}}$. He will choose $R_1=\pi_H-\frac{m_H+\overline{u}}{\mu\left(G|\iota_{E_1},\iota_{E_2}\right)p}$ if and only if:

$$\mu\left(G|\iota_{E_2}\right)p\pi_H-(m_H+\overline{u})\frac{\mu\left(G|\iota_{E_2}\right)}{\mu\left(G|\iota_{E_1},\iota_{E_2}\right)}-(1-m_H)+p\mu\left(G|\iota_{E_2}\right)\left(p\pi_H-\overline{u}-1\right)\geq 0. \tag{A.4}$$

Note that (A.2) $\iff$ (A.4) and (A.1) $>$ (A.3). Thus, if (A.4) holds, then the investor is better off choosing $e^0_K=0$. If (A.4) does not hold, then the investor's payoff if $e^0_K=1$ is $d-z_{\iota_{E_2}}$, while his payoff if $e^0_K=0$ is $d>d-z_{\iota_{E_2}}$. Therefore, the investor chooses $e^0_K=0$ and we have a contradiction. ■

Proof of Lemma 3. If $e^0_K=0$, the entrepreneur of type ι_{E_1} believes his project is of type G with probability $\mu_{\iota_{E_1}}\left(G|\iota_{E_1},z\right)\equiv\sum\limits_{\iota'_{E_2}\in K(T)}\mu_{\iota_{E_1}}\left(\iota'_{E_2}|\iota_{E_1},z\right)\mu\left(G|\iota'_{E_2},\iota_{E_1}\right)$. Therefore, his expected payoff is:

$$e^0_{\iota_{E_1}}\mu_{\iota_{E_1}}\left(G|\iota_{E_1},z\right)p\left(\pi_H-R_0\right)+\left(1-e^0_{\iota_{E_1}}\right)\left(m_H+\overline{u}\right).$$

He will choose $e^0_{\iota_{E_1}}=1$ if and only if:

$$\mu_{\iota_{E_1}}\left(G|\iota_{E_1},z\right)p\left(\pi_H-R_0\right)\geq m_H+\overline{u}.$$

If $\iota_{E_1}=\{B\}$, we have $\mu_{\iota_{E_1}}\left(G|\iota_{E_1},z\right)=0$ and $e^0_{\{B\}}=0\ \forall R_0\in\mathbb{R}^+$. If $\iota_{E_1}=\{G\}$, then $\mu_{\iota_{E_1}}\left(G|\iota_{E_1},z\right)=1$ and $e^0_{\{G\}}=1$ if and only if $R_0\leq\pi_H-\frac{m_H+\overline{u}}{p}\equiv\overline{R_0}$. If $\iota_{E_1}=\{U\}$, then $\mu_{\iota_{E_1}}\left(G|\iota_{E_1},z\right)=\lambda$ and $e^0_{\{U\}}=1$ if and only if $R_0\leq\pi_H-\frac{m_H+\overline{u}}{\lambda p}\equiv\underline{R_0}$. The argument is the same if $e^0_K=1$, which concludes the proof. ■

Proof of Lemma 4. One must note that, given the strategies chosen by the entrepreneurs, the expected payoff of the investor is increasing in R_0. If it is optimal for the investor to choose $R_0\in\left[0,\underline{R_0}\right]$, only the entrepreneurs of types $\{U\}$ and $\{G\}$ will accept the contract. Hence, the investor chooses $R_0=\underline{R_0}$. If it is optimal to choose $R_0\in\left(\underline{R_0},\overline{R_0}\right]$ only the entrepreneur of type $\{G\}$ will accept the contract and the investor chooses $R_0=\overline{R_0}$. For $R_0>\overline{R_0}$ no entrepreneur will accept the contract and the investor's expected return is d. In this case a contract with price $R_0=\overline{R_0}$ gives the investor a higher payoff. To see this, note that the investor's belief that the entrepreneur is of type ι_{E_1} is $\mu_K(\iota_{E_1}|z) = \sum_{\iota'_{E_2}\in K(z)} \mu_K(\iota'_{E_2}|z)\,\mu(\iota_{E_1}|\iota'_{E_2})$ the expected payoff of the investor if he charges $\overline{R_0}$ is

$$\mu_K(\{B\}|z)\,d + \mu_K(\{U\}|z)\,d + \mu_K(\{G\}|z)\,[pR_0 + d - (1-m_H)] + \mu_K(\{G\}|z)\,p\,(p\pi_H - \overline{u} - 1) =$$
$$d + \mu_K(\{G\}|z)\,[p\pi_H(1+p) - (m_H + \overline{u}) - 1] > d,$$

which is positive since $\mu_K(\{G\}|z) = \lambda q$ and we assume $\pi_H - \frac{m_H+\overline{u}}{\lambda p} > 1$. ■

Proof of Lemma 5. Suppose in equilibrium $e_K = 1$. If all types of VC report the same information τ, then consistency implies the following beliefs for the investor $\mu_K(\{G\}|z) = \mu_K(\{G\}|z,\tau) = \lambda q$, $\mu_K(\{B\}|z) = \mu_K(\{B\}|z,\tau) = (1-\lambda)\,q$, $\mu_K(\{U\}|z) = \mu_K(\{U\}|z,\tau) = 1-q$. The implied beliefs for entrepreneur E_1 are $\mu_{E_1}(G|\{G\},z) = \mu_{E_1}(G|\{G\},z,\tau) = 1$, $\mu_{E_1}(G|\{B\},z) = \mu_{E_1}(G|\{B\},z,\tau) = 0$, and $\mu_{E_1}(G|\{U\},z) = \mu_{E_1}(G|\{U\},z,\tau) = \lambda$. Therefore, the same argument used in the proof of lemma 2 applies and the investor is better off choosing $e_K = 0$, which leads to a contradiction. ■

Proof of Lemma 6. Suppose it is not , i.e., $1 > d - (1-m_H) + R_k$. Since an optimal debt contract has a price $R_k \in \{\underline{R_k}, \overline{R_k}\}$, the assumption $\pi_H - \frac{m_H+\overline{u}}{\lambda p} > 1$ implies $R_k > 1$. Therefore, $d-(1-m_H)+R_k > 1+d-(1-m_H) \geq 1 > d-(1-m_H)+R_k \Rightarrow 1 > R_k$, which is a contradiction. ■

Proof of Proposition 1. By lemma 4, we need only consider four types of equilibria: $\tau_{\{G\}} \neq \tau_{\{U\}} \neq \tau_{\{B\}}$; $\tau_{\{U\}} = \tau_{\{B\}} = \tau$, $\tau_{\{G\}} \neq \tau$; $\tau_{\{G\}} = \tau_{\{U\}} = \tau$, $\tau_{\{B\}} \neq \tau$; $\tau_{\{G\}} = \tau_{\{B\}} = \tau$, $\tau_{\{U\}} \neq \tau$. In order to characterize VC-equilibria, we need to find the optimal strategy for the investor given his beliefs, check if the reports given by VCs are optimal given the investor's beliefs, and see whether $e_K = 1$ is optimal for the investor. The expected payoff of the VC of type ι_{E_2} is $\sum_{\iota_{E_1}\in T} e^1_{\iota_{E_1}}\,\mu(\iota_{E_1}|\iota_{E_2})\,\mu(G|\iota_{E_1},\iota_{E_2})\,p\overline{u}$. The investor's expected payoff is

$$\sum_{\iota_{E_1}\in T} \mu_K(\iota_{E_1}|z,\tau) \left[\begin{array}{c} e^1_{\iota_{E_1}}\left(R_1\left(\tau_{\iota_{E_2}}\right)\right)\left(\mu(G|\iota_{E_1})\,pR_1\left(\tau_{\iota_{E_2}}\right) + d - (1-m_H) - z\right) + \\ \left(1 - e^1_{\iota_{E_1}}\left(R_1\left(\tau_{\iota_{E_2}}\right)\right)\right)(d-z) + e^1_{\iota_{E_1}}\,\mu(G|\iota_{E_1})\,p\,(p\pi_H - \overline{u} - 1) \end{array} \right].$$

Case 1 ($\tau_{\{G\}} \neq \tau_{\{U\}} \neq \tau_{\{B\}}$): Suppose $\underline{\Pi}(q=0) - d > 0$. In these equilibria $\mu_K\left(\iota_{E_2}|z,\tau_{\iota_{E_2}}\right) = 1$, $\mu_K\left(\iota_{E_1}|z,\tau_{\iota_{E_2}}\right) = \mu(\iota_{E_1}|\iota_{E_2})$. If $\iota_{E_2} = \{G\}$, then the investor clearly chooses $\underline{R_1}\left(\tau_{\{G\}}\right) = \overline{R_1}$ and receives a payoff of $\overline{\Pi}(\lambda=1, q=1) - z$. If $\iota_{E_2} = \{U\}$, then $\mu_{E_1}(G|\iota_{E_1},z,\tau) = \lambda$ and $\underline{R_1}\left(\tau_{\{U\}}\right) = \pi_H - \frac{m_H+\overline{u}}{\lambda p}$. The investor receives a payoff of $d - z$ if $R_1 > \underline{R_1}\left(\tau_{\{U\}}\right)$ and a payoff of $\underline{\Pi}(q=0) - z$ if $R_1 = \underline{R_1}\left(\tau_{\{U\}}\right)$. Since $\underline{\Pi}(q=0) - d > 0$, the investor chooses $R_1\left(\tau_{\{U\}}\right) = \underline{R_1}\left(\tau_{\{U\}}\right)$. If $\iota_{E_2} = \{B\}$, then the investor's payoff is $d - z$ $\forall R_1 \in \mathbb{R}^+$. The expected payoff of the VC of type $\iota_{E_2} = \{G\}$ is $p\overline{u}$ independent of his report, so he has no incentive to deviate. The expected payoff of the VC of type $\iota_{E_2} = \{U\}$ is $\lambda p\overline{u}$ if he reports $\tau_{\{U\}}$ and at most $\lambda p\overline{u}$ if he reports either $\tau_{\{G\}}$ or $\tau_{\{B\}}$. Therefore, he has no incentive to deviate. The expected payoff of the VC of type $\iota_{E_2} = \{B\}$

is 0 regardless of his report and he has no reason to deviate. The ex ante expected payoff of the investor is

$$\Pi = \overline{\Pi} + (1-q)\left(\underline{\Pi}(q=0) - d\right) = \underline{\Pi} + q(1-\lambda)(m_H + \overline{u}) > \max\left\{\overline{\Pi}, \underline{\Pi}\right\},$$

and the investor chooses $e_K = 1$ if $z \leq \min\left\{d - (1-m_H), \Pi - \max\left\{\overline{\Pi}, \underline{\Pi}\right\}\right\}$, and $e_K = 0$ otherwise. Consequently, VCs will optimally set $z = \min\left\{d - (1-m_H), \Pi - \max\left\{\overline{\Pi}, \underline{\Pi}\right\}\right\}$ and we have a characterization of VC-equilibria when $\underline{\Pi}(q=0) - d > 0$.

Suppose now there is a VC equilibrium with $\underline{\Pi}(q=0) - d \leq 0$. If $\underline{\Pi}(q=0) - d = 0$ and $R_1\left(\tau_{\{U\}}\right) = \underline{R_1}\left(\tau_{\{U\}}\right)$, then we know a VC-equilibrium cannot exist since $z = 0$ in this case, which leads to a contradiction. If $R_1\left(\tau_{\{U\}}\right) > \underline{R_1}\left(\tau_{\{U\}}\right)$, then the VC of type $\iota_{E_2} = \{U\}$ has an incentive to deviate and report $\tau_{\{B\}}$ provided that $R_1\left(\tau_{\{B\}}\right) \leq \underline{R_1}\left(\tau_{\{U\}}\right)$. Therefore, we must have $R_1\left(\tau_{\{B\}}\right) > \underline{R_1}\left(\tau_{\{U\}}\right)$ in order to sustain such equilibria. However, the investor's ex ante payoff under informed finance is $\overline{\Pi} \leq \max\left\{\overline{\Pi}, \underline{\Pi}\right\}$, which implies $z = 0$ and we have a contradiction. If $\underline{\Pi}(q=0) - d < 0$ then it must be that $R_1\left(\tau_{\{U\}}\right) > \underline{R_1}\left(\tau_{\{U\}}\right)$ and we already know that $z = 0$, leading to a contradiction. Hence, a VC-equilibrium exists if and only if $\underline{\Pi}(q=0) - d > 0$.

Case 2 ($\tau_{\{U\}} = \tau_{\{B\}} = \tau$, $\tau_{\{G\}} \neq \tau$)**:** Suppose $\underline{\Pi}(q=0) - d > 0$. In these equilibria $\mu_K\left(\{G\}|z, \tau_{\{G\}}\right) = 1$, $\mu_K(\{U\}|z,\tau) = \frac{1-q}{1-q+(1-\lambda)q}$, and $\mu_K(\{B\}|z,\tau) = \frac{(1-\lambda)q}{1-q+(1-\lambda)q}$. If $\iota_{E_2} = \{G\}$, then the investor chooses $R_1\left(\tau_{\{IG\}}\right) = \overline{R_1}$, receiving a payoff of $\overline{\Pi}(\lambda = 1, q = 1) - z$. Note that $\mu_{E_1}(G|\{U\}, z, \tau) = \lambda$, which implies $\underline{R_1}(\tau) = \pi_H - \frac{m_H + \overline{u}}{\lambda p}$. If the investor chooses $R_1 > \underline{R_1}(\tau)$ upon receiving a report from either type $\{U\}$ or type $\{B\}$, his payoff is $d - z$. If he chooses $R_1 = \underline{R_1}(\tau)$ instead:

$$\frac{1-q}{1-q+(1-\lambda)q}\left(\underline{\Pi}(q=0) - z\right) + \frac{(1-\lambda)q}{1-q+(1-\lambda)q}(d-z).$$

Therefore, the investor will choose $R_1(\tau) = \underline{R_1}(\tau)$. Clearly, no VC has an incentive to deviate regardless of $R_1(\tau')$ for $\tau' \in T\backslash\left\{\tau, \tau_{\{G\}}\right\}$, which implies the investor can have any belief upon receiving report τ'. As a consequence, the investor's ex ante payoff will be $\overline{\Pi} + (1-q)\left(\underline{\Pi}(q=0) - d\right)$ and the investor chooses $e_K = 1$ if $z \leq \min\left\{d - (1-m_H), \Pi - \max\left\{\overline{\Pi}, \underline{\Pi}\right\}\right\}$, and $e_K = 0$ otherwise. VCs charge $z = \min\left\{d - (1-m_H), \Pi - \max\left\{\overline{\Pi}, \underline{\Pi}\right\}\right\}$. Thus, we characterized the VC-equilibria when $\underline{\Pi}(q=0) - d > 0$. Suppose now there is a VC equilibrium with $\underline{\Pi}(q=0) - d \leq 0$. The argument that leads to a contradiction is that same as that in Case 1. Therefore, a VC-equilibrium exists if and only if $\underline{\Pi}(q=0) - d > 0$.

Case 3 ($\tau_{\{G\}} = \tau_{\{U\}} = \tau$, $\tau_{\{B\}} \neq \tau$)**:** Suppose $\underline{\Pi}(q=0) - d > 0$. In this equilibria $\mu_K\left(\{B\}|z, \tau_{\{B\}}\right) = 1$, $\mu_K(\{U\}|z,\tau) = \frac{1-q}{1-q+\lambda q}$, and $\mu_K(\{G\}|z,\tau) = \frac{\lambda q}{1-q+\lambda q}$. Since the uninformed entrepreneur has belief $\mu_{E_1}(G|\{U\}, z, \tau) = \lambda$ that the holds a good project, if the investor chooses $\underline{R_1}(\tau) = \pi_H - \frac{m_H + \overline{u}}{\lambda p}$ upon receiving a report from either type $\{U\}$ or type $\{G\}$, his expected payoff will be $\frac{\Pi - (1-\lambda)qd}{1-q+\lambda q} - z$. If the investor chooses $\overline{R_1}$ instead, his expected payoff will be

$\frac{\overline{\Pi}-(1-\lambda)qd}{1-q+\lambda q} - z$. Therefore, if $\overline{\Pi} > \underline{\Pi}$ the investor chooses $R_1(\tau) = \overline{R_1}$, and if $\overline{\Pi} < \underline{\Pi}$ the investor chooses $R_1(\tau) = \underline{R_1}(\tau)$. Regarding a report from the VC of type $\{B\}$, $e^1_{\{B\}} = 0$ and the investor's expected payoff is $d - z \ \forall R_1 \in \mathbb{R}^+$. The VC of type $\{G\}$ has clearly on incentive to deviate. If $\overline{\Pi} > \underline{\Pi}$ the VC of type $\{U\}$ has an incentive to deviate provided that either $R_1(\tau')$ or $R_1\left(\tau_{\{B\}}\right)$ is less than or equal to $\underline{R_1}(\tau)$ for $\tau' \in T \backslash \left\{\tau, \tau_{\{B\}}\right\}$. In this case, has an expected payoff of 0 if he reports τ and $\lambda p \overline{u}$ otherwise. Thus, we must have $R_1(\tau'), R_1\left(\tau_{\{B\}}\right) > \underline{R_1}(\tau)$ to sustain such equilibria. However, the investor's ex ante payoff under informed finance is $\Pi = \overline{\Pi} \leq \max\left\{\overline{\Pi}, \underline{\Pi}\right\}$ and he is better off choosing $e_K = 0$. Hence, no VC-equilibrium exists if $\overline{\Pi} > \underline{\Pi}$. If $\overline{\Pi} < \underline{\Pi}$ then no VC has incentive to deviate regardless of $R_1(\tau')$ and $R_1\left(\tau_{\{B\}}\right)$, which implies the investor can have any belief upon receiving report τ'. However, the investor's ex ante payoff will be $\Pi = \underline{\Pi} \leq \max\left\{\overline{\Pi}, \underline{\Pi}\right\}$ and he is better off choosing $e_K = 0$. Therefore, there is no VC-equilibrium if $\overline{\Pi} < \underline{\Pi}$. Conversely, there is no VC-equilibrium if $\underline{\Pi}(q=0) - d \leq 0$ since in this case the investor must choose $R_1(\tau) = \overline{R_1}$ and we know the implied investor's expected payoff is $\Pi = \overline{\Pi} \leq \max\left\{\overline{\Pi}, \underline{\Pi}\right\}$.

Case 4 ($\tau_{\{G\}} = \tau_{\{B\}} = \tau$, $\tau_{\{U\}} \neq \tau$): Suppose $\underline{\Pi}(q=0) - d > 0$. In this equilibrium $\mu_K\left(\{U\}|z, \tau_{\{U\}}\right) = 1$, $\mu_K(\{B\}|z,\tau) = \frac{(1-\lambda)q}{(1-\lambda)q+\lambda q}$, and $\mu_K(\{G\}|z,\tau) = \frac{\lambda q}{(1-\lambda)q+\lambda q}$. Since the uninformed entrepreneur has belief $\mu_{E_1}\left(G|\{U\}, z, \tau_{\{U\}}\right) = \lambda$ that he has a good project, $\underline{R_1}\left(\tau_{\{U\}}\right) = \pi_H - \frac{m_H+\overline{u}}{\lambda p}$. If the investor chooses $R_1 > \underline{R_1}\left(\tau_{\{U\}}\right)$ upon receiving a report from the VC of type $\{U\}$, his expected payoff is $d - z$. If he chooses $R_1 = \underline{R_1}\left(\tau_{\{U\}}\right)$, his expected payoff is $\underline{\Pi}(q=0) - z$. Therefore, the investor chooses $R_1\left(\tau_{\{U\}}\right) = \underline{R_1}\left(\tau_{\{U\}}\right)$. The investor will clearly choose $\overline{R_1}$ upon receiving the report τ, which implies $R_1(\tau) = \overline{R_1}$ and an associated payoff of $\frac{\overline{\Pi}-(1-\lambda)qd}{1-q+\lambda q} - z$. It is straightforward to check that no VC has an incentive to deviate regardless of regardless of $R_1(\tau')$ for $\tau' \in T \backslash \left\{\tau, \tau_{\{U\}}\right\}$. Therefore, there are no restrictions on the investor's belief upon receiving report τ'. The investor's ex ante payoff under informed finance is $\Pi = \underline{\Pi} + (1-q)\left(\underline{\Pi}(q=0) - d\right) > \max\left\{\overline{\Pi}, \underline{\Pi}\right\}$. The investor chooses $e_K = 1$ if $z \leq \min\left\{d - (1-m_H), \Pi - \max\left\{\overline{\Pi}, \underline{\Pi}\right\}\right\}$ and $e_K = 0$ if otherwise, and the VCs will optimally choose $z = \min\left\{d - (1-m_H), \Pi - \max\left\{\overline{\Pi}, \underline{\Pi}\right\}\right\}$. We have characterized the VC-equilibria when $\underline{\Pi}(q=0) - d > 0$. The argument to show that no VC-equilibrium exists if $\underline{\Pi}(q=0) - d \leq 0$ is the same as that in Case 1.

Therefore, we have shown that a VC-equilibrium exists if and only if $\underline{\Pi}(q=0) - d > 0$. Moreover, we have characterized the VC-equilibria and they are all payoff-equivalent. ■

Proof of Proposition 2. We start by showing (i). The payoff of the VC of type ι_{E_2} is $\sum_{\iota_{E_1} \in T} e^1_{\iota_{E_1}} \mu\left(\iota_{E_1}|\iota_{E_2}\right) \mu\left(G|\iota_{E_1}, \iota_{E_2}\right) p\overline{u}$, and the investor's expected payoff upon receiving a report from VCs is

$$\sum_{\iota_{E_1} \in T} \mu_K\left(\iota_{E_1}|z,\tau\right) \left[\begin{array}{c} e^1_{\iota_{E_1}}\left(R_1\left(\tau_{\iota_{E_2}}\right)\right)\left(\mu\left(G|\iota_{E_1}\right) p R_1\left(\tau_{\iota_{E_2}}\right) + d - (1-m_H) - z\right) + \\ \left(1 - e^1_{\iota_{E_1}}\left(R_1\left(\tau_{\iota_{E_2}}\right)\right)\right)(d-z) + e^1_{\iota_{E_1}} \mu\left(G|\iota_{E_1}\right) p\left(p\pi_H - \overline{u} - 1\right) \end{array} \right].$$

To see a separating equilibrium exists, first note that $\mu_K\left(\iota_{E_2}|z, \tau_{\iota_{E_2}}\right) = 1$. If $\iota_{E_2} = \{G\}$, then

$\mu_{E_1}\left(G|\left\{U\right\},z,\tau_{\{G\}}\right) = 1$, which implies $\underline{R_1}\left(\tau_{\{G\}}\right) = \overline{R_1}$. Thus, the investor optimally chooses $R_1\left(\tau_{\{G\}}\right) = \overline{R_1}$ and receives a payoff of $\overline{\Pi}\left(\lambda = 1, q = 1\right) - z$. If $\iota_{E_2} = \{U\}$, then the uninformed entrepreneur believes with probability $\mu_{E_1}\left(G|\left\{U\right\},z,\tau_{\{G\}}\right) = \lambda$ that he holds a good project and $\underline{R_1}\left(\tau_{\{U\}}\right) = \pi_H - \frac{m_H+\overline{u}}{\lambda p}$. The investor's expected payoff if he chooses $\overline{R_1}$ is $\overline{\Pi} - z$, whereas his payoff if he chooses $\underline{R_1}\left(\tau_{\{U\}}\right)$ is $\underline{\Pi} - z$. This implies $R_1\left(\tau_{\{U\}}\right) = \overline{R_1}$ since $\overline{\Pi} > \underline{\Pi}$. If $\iota_{E_2} = \{B\}$, then the investor's payoff is $d - z\,\forall R_1 \in \mathbb{R}^+$. The VC of type $\{G\}$ has not incentive to deviate since he receives a payoff of $qp\overline{u} + (1-q)\lambda p\overline{u}$ if he conforms, and at most this amount if he deviates. If $R_1\left(\tau_{\{B\}}\right) \leq \underline{R_1}\left(\tau_{\{U\}}\right)$, then the VC of type $\{U\}$ has an incentive to deviate and report $\tau_{\{B\}}$. To see this note that he gets a payoff of $\lambda p\overline{u}$ if he deviates compared to a payoff of $\lambda qp\overline{u}$ if otherwise. Hence, to sustain such equilibria we need $R_1\left(\tau_{\{B\}}\right) > \underline{R_1}\left(\tau_{\{U\}}\right)$. The investor's ex ante expected payoff is $\overline{\Pi} + (1-q)\left(\overline{\Pi} - d\right)$ and VCs optimally choose $z = \min\left\{d - (1 - m_H), (1-q)\left(\overline{\Pi} - d\right)\right\}$.

For the semi-pooling equilibria in which $K(\tau) = \{\{U\},\{B\}\}$, we have $\mu_K\left(\{G\}|z,\tau_{\{G\}}\right) = 1$, $\mu_K\left(\{U\}|z,\tau\right) = \frac{1-q}{1-q+q(1-\lambda)}$ and $\mu_K\left(\{B\}|z,\tau\right) = \frac{q(1-\lambda)}{1-q+q(1-\lambda)}$. If $\iota_{E_2} = \{G\}$, then the uninformed entrepreneur has belief $\mu_{E_1}\left(G|\left\{U\right\},z,\tau_{\{G\}}\right) = 1$ that he holds a good project, which implies $\underline{R_1}\left(\tau_{\{G\}}\right) = \overline{R_1}$. The investor chooses $R_1\left(\tau_{\{G\}}\right) = \overline{R_1}$ and receives a payoff of $\overline{\Pi}\left(\lambda = 1, q = 1\right) - z$. Following report τ, the uninformed entrepreneur has belief $\mu_{E_1}\left(G|\left\{U\right\},z,\tau\right) = \frac{(1-q)\lambda}{(1-q)+q(1-\lambda)}$ that his project is good, which implies $\underline{R_1}(\tau) = \pi_H - \left(\frac{1-\lambda q}{1-q}\right)\frac{m_H+\overline{u}}{\lambda p}$. Calculating expected payoffs, the investor receives a payoff of

$$\frac{1}{1-q+q(1-\lambda)}\left[(1-q)\lambda q\left(\overline{\Pi}\left(\lambda = 1, q = 1\right) - d\right)\right] + d - z.$$

if he chooses $\overline{R_1}$ and a payoff of

$$\frac{1}{1-q+q(1-\lambda)}\left[(1-q)\lambda q\left(\overline{\Pi}\left(\lambda = 1, q = 1\right) - d\right)\right] + \underline{\Pi} - \overline{\Pi} - \frac{q(1-\lambda)}{1-q+q(1-\lambda)}\left(m_H + \overline{u}\right) + d - z.$$

Therefore, the investor chooses $R_1(\tau) = \overline{R_1}$ since $\underline{\Pi} - \overline{\Pi} < 0$. We need to check that no VC wants to deviate. The VC of type $\{G\}$ receives a payoff the of $(1-q)\lambda p\overline{u} + qp\overline{u}$ if he conforms with $\tau_{\{G\}}$ and at most $(1-q)\lambda p\overline{u} + qp\overline{u}$ if he deviates. Thus, he has no incentive to deviate. The VC of type $\{B\}$ receives a payoff of 0 in any outcome and therefore has no incentive to deviate either. The VC of type $\{U\}$ receives a payoff of $q\lambda p\overline{u}$ if he conforms and a payoff of $\lambda p\overline{u}$ if he deviates to $R_1(\tau')$, provided that $R_1(\tau') \leq \underline{R_1}(\tau)$ for $\tau' \in T\backslash\left\{\tau,\tau_{\{G\}}\right\}$. Hence, $R_1(\tau') > \underline{R_1}(\tau)$ to sustain such equilibria. The investor ex ante payoff is $\overline{\Pi} + (1-q)\left(\overline{\Pi} - d\right)$, and VCs optimally charge $\min\left\{d - (1 - m_H), (1-q)\left(\overline{\Pi} - d\right)\right\}$.

For (ii), we have $\mu_K\left(\{B\}|z,\tau_{\{IB\}}\right) = 1$, $\mu_K\left(\{U\}|z,\tau\right) = \frac{1-q}{1-q+\lambda q}$ and $\mu_K\left(\{G\}|z,\tau\right) = \frac{\lambda q}{1-q+\lambda q}$. If $\iota_{E_2} = \{B\}$, then $\mu_{E_1}\left(G|\left\{U\right\},z,\tau_{\{B\}}\right) = 0$ and the investor's payoff is $d - z$ for all $R_1 \in \mathbb{R}^+$. The uninformed entrepreneur has belief $\mu_{E_1}\left(G|\left\{U\right\},z,\tau\right) = \frac{\lambda}{1-q+\lambda q}$ that his holds a good project upon observing report τ, which implies $\underline{R_1}(\tau) = \pi_H - (1 - q + \lambda q)\frac{m_H+\overline{u}}{\lambda p}$. If the investor chooses

$R_1 = \overline{R_1}$ his expected payoff is

$$\frac{1}{1-q+\lambda q}\left[\lambda q\left(\overline{\Pi}\left(\lambda=1, q=1\right)-d\right)\right]+d-z,$$

while if he chooses $R_1 = \underline{R_1}(\tau)$ his payoff is

$$\frac{1}{1-q+\lambda q}\left[\lambda q\left(\overline{\Pi}\left(\lambda=1, q=1\right)-d\right)\right]+(1-q)\left(\underline{\Pi}\left(q=0\right)-d\right)-$$
$$(1-q)\frac{\left[q\left(1-\lambda\right)\right]^2}{1-q\left(1-\lambda\right)}\left(m_H+\overline{u}\right)+d-z.$$

If $(1-q)\left(\underline{\Pi}\left(q=0\right)-d\right)-(1-q)\frac{[q(1-\lambda)]^2}{1-q(1-\lambda)}\left(m_H+\overline{u}\right)\geq 0$ then the investor is indifferent between choosing $\overline{R_1}$ or $\underline{R_1}(\tau)$. Suppose he chooses the latter, i.e., $R_1(\tau) = \underline{R_1}(\tau)$. The VC of type $\{G\}$ receives $(1-q)\lambda p\overline{u}+qp\overline{u}$ and at most this amount if he deviates. Analogously, the VC of type $\{U\}$ receives a payoff of $\lambda p\overline{u}$ if he conforms and at most this quantity if he deviates. The VC of type $\{B\}$ receives 0 in any outcome and has clearly no incentive to deviate. The investor's ex ante payoff in this type of equilibria is $\overline{\Pi}+(1-q)\left(\underline{\Pi}-d\right)$ and VCs optimally choose $z = \min\left\{d-(1-m_H), (1-q)\left(\underline{\Pi}-d\right)\right\}$. If the investor chooses the former, then the VCs of type $\{G\}$ and $\{U\}$ want to deviate provided that either $R_1\left(\tau_{\{B\}}\right)\leq\underline{R_1}(\tau)$ or $R_1(\tau')\leq\underline{R_1}(\tau)$ for $\tau'\in T\backslash\left\{\tau,\tau_{\{B\}}\right\}$. To see this, note that the VC of type $\{G\}$ receives a payoff of $qp\overline{u}$ and the VC of type $\{U\}$ receives a payoff of $\lambda qp\overline{u}$ if they conform. If they deviate and report either $\tau_{\{B\}}$ or τ' they receive payoffs of $qp\overline{u}+(1-q)\lambda p\overline{u}$ and $\lambda qp\overline{u}+(1-q)\lambda p\overline{u}$ respectively. Thus, we need both $R_1\left(\tau_{\{B\}}\right)>\underline{R_1}(\tau)$ and $R_1(\tau')>\underline{R_1}(\tau)$ to sustain such equilibria. However, this type of equilibria give the investor an ex ante expected payoff of $\overline{\Pi}$, and no VC-equilibria exist. If $(1-q)\left(\underline{\Pi}\left(q=0\right)-d\right)-(1-q)\frac{[q(1-\lambda)]^2}{1-q(1-\lambda)}\left(m_H+\overline{u}\right)<0$ then the investor must choose $R_1(\tau)=\overline{R_1}$ and we already know a VC-equilibrium does not exist in this situation. Therefore, VC-equilibria in which $K(\tau)=\{\{G\},\{U\}\}$ exist if and only if $(1-q)\left(\underline{\Pi}\left(q=0\right)-d\right)-(1-q)\frac{[q(1-\lambda)]^2}{1-q(1-\lambda)}\left(m_H+\overline{u}\right)\geq 0$.

To show (iii), note that $\mu_K\left(\{U\}|z,\tau_{\{B\}}\right)=1$, $\mu_K\left(\{G\}|z,\tau\right)=\lambda$ and $\mu_K\left(\{B\}|z,\tau\right)=1-\lambda$. If $\iota_{E_2}=\{U\}$, then $\mu_{E_1}\left(G|\{U\},z,\tau_{\{U\}}\right)=\lambda$, which implies $\underline{R_1}\left(\tau_{\{U\}}\right)=\pi_H-\frac{m_H+\overline{u}}{\lambda p}$. If the investor chooses $\overline{R_1}$ he receives a payoff of $\lambda q\left(\overline{\Pi}\left(\lambda=1,q=1\right)-d\right)+d-z$. If he chooses $\underline{R_1}\left(\tau_{\{U\}}\right)$ his payoff is

$$\lambda q\left(\overline{\Pi}\left(\lambda=1,q=1\right)-d\right)+(1-q)\left(\underline{\Pi}\left(q=0\right)-d\right)-q\left(1-\lambda\right)\left(m_H+\overline{u}\right)+d-z.$$

Therefore, he chooses $\underline{R_1}\left(\tau_{\{U\}}\right)$ only if $(1-q)\left(\underline{\Pi}\left(q=0\right)-d\right)-q\left(1-\lambda\right)\left(m_H+\overline{u}\right)\geq 0$. After observing τ the uninformed entrepreneur believes he holds a good project with probability $\mu_{E_1}\left(G|\{U\},z,\tau\right)=\lambda$, which implies $\underline{R_1}(\tau)=\pi_H-\frac{m_H+\overline{u}}{\lambda p}$. Therefore, the expected investor's expected payoff is the same as that when he faces the VC of type $\{U\}$. This in turn implies that he chooses $\underline{R_1}(\tau)$ only if $(1-q)\left(\underline{\Pi}\left(q=0\right)-d\right)-q\left(1-\lambda\right)\left(m_H+\overline{u}\right)\geq 0$. If $(1-q)\left(\underline{\Pi}\left(q=0\right)-d\right)-$

$q(1-\lambda)(m_H+\overline{u})<0$, then the investor chooses $R_1(\tau_U)=R_1(\tau)=\overline{R_1}$ and a VC-equilibrium, if it exists, gives the investor an ex ante expected payoff of $\overline{\Pi}$. But then $e_K=0$ and we have a contradiction, which implies a VC-equilibrium does not exist. Suppose $(1-q)(\underline{\Pi}(q=0)-d)-q(1-\lambda)(m_H+\overline{u})\geq 0$. Without loss of generality, assume the investor chooses $R_1(\tau_U)=R_1(\tau)=\underline{R_1}(\tau)$. Clearly no VC has an incentive to deviate and then investor's implied ex ante expected payoff is $\underline{\Pi}$, which implies a VC-equilibrium does not exist. ■

Proof of Proposition 3. Suppose they are strong announcement-proof. We claim that the announcement $\langle D,P\rangle$ with $P=D=\{\{G\},\{U\}\}$ is a credible announcement relative these equilibria. If this announcement is believed, then the beliefs of investors and entrepreneurs are updated according to (12). In particular, the beliefs of the investor and uninformed entrepreneur are the same as in the proof of (ii) of Proposition 2: $\widehat{\mu}_K(\{U\}|z,D)=\frac{1-q}{1-q+\lambda q}$, $\widehat{\mu}_K(\{G\}|z,D)=\frac{1-q}{1-q+\lambda q}$, and $\mu_{E_1}(G|\{U\},z,D)=\frac{\lambda}{1-q+\lambda q}$. Therefore, the equilibria induced by these beliefs are the same as those in (ii) of Proposition 2 and this announcement is *credible* since: (1) the payoff of the VC of type $\{IG\}$ in (ii) is the same as his payoff in (i), (2) the payoff of the VC of type $\{U\}$ in (ii) is strictly preferred to his payoff in (i), (3) the payoff of the VC of type $\{B\}$ in (ii) is the same as his payoff in (i), and (4) there is clearly no other announcement that, if believed, could increase the payoffs of the VCs of types $\{G\}$ and $\{U\}$. Hence, we have a contradiction. That the equilibria in (ii) of Proposition 2 are strongly announcement-proof follows from the observation that all VCs receive their maximum expected payoff in those equilibria. ■

Proof of Proposition 4. We omit the proof of Proposition 4 since it is nearly identical to that of Proposition 2. ■

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