Convertible Preferred Stock in Venture Capital Financing*

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Abstract

We provide an explanation for the widespread use of senior convertible preferred stock in venture capital financing. We develop a model of cash constrained entrepreneurs who need an investor to finance their project. Investors can either be uninformed, such as small individual bondholders, or informed, such as venture capitalists and banks. There is an entrepreneurial moral hazard problem, which can be partially overcome through monitoring only by informed investors. However, monitoring is only effective if investors can commit ex ante to liquidate the project after observing a poor signal. We show that a capital structure that minimizes commitment and information costs requires entrepreneurs to contribute to the financing of the project with common stock and venture capitalists to hold senior convertible preferred stock.

JEL Classification: G21, G24, G32, G33

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1 Introduction

Recent empirical research on venture capital has provided a wealth of information about financial contracting in newly established entrepreneurial ventures. Kaplan and Strömberg (2003) find that the most commonly used security by venture capitalists (VC) is convertible preferred stock. This type of security provides its owner with the right to convert to common shares of stock and has certain rights that common stock does not have, such as a specified dividend that normally accrues and senior priority in receiving proceeds from a sale or liquidation of the company. Therefore, it provides downside protection due to its negotiated rights and allows investors to profit from share appreciation through conversion.

In many cases, convertible preferred stock automatically converts to common stock if the company makes an initial public offering (IPO). More generally, conversion is decided upon the realization of an observable contingency, like reaching a production or research milestone or achieving a certain financial performance. The evidence from the US market shows that the large majority of venture capital financing explicitly include some type of contingency and that the final payoffs of the founders and VCs depend upon it.

This article provides an explanation for the use of convertible preferred stock in venture capital financing. We show that in a setting where there is entrepreneurial moral hazard, convertible preferred stock minimizes the investor's commitment costs. Ex-ante investors want to liquidate poorly performing ventures. Ex-post, however, when assets are specific and liquidation leads to a loss, investors choose to renegotiate the terms of financing rather than liquidate. By granting VCs senior priority claims and the downside protection of a debt contract, convertible preferred stock gives investors the incentives to monitor and liquidate bad projects. As potential equity holders, investors are willing to put up with the costs of monitoring if this promotes managerial efficiency and increases expected profits. At the same time, as senior debtholders, investors are sheltered from the loss of liquidation because the founders have provided a 'cash cushion' that they can rely upon.

Consider the case when entrepreneurs are capital constrained and project profitability depends on unobservable entrepreneurial effort. A suboptimal level of effort is provided unless entrepreneurs are given the incentive to do otherwise. Unobservability of effort generates entrepreneurial moral hazard.

As a result, investors need to write incentive compatible contracts which reward entrepreneurs with a high payoff when project returns are high and punish them with a low payoff when project returns are low.

We show that when only uninformed investors, such as small individual investors, are available, debt represents the best form of financing because it gives entrepreneurs the incentive to work: entrepreneurs are rewarded with positive returns in the high state and punished with a zero payoff in the low state. The main disadvantage of debt is that it provides returns which are limited upwards. This reduces the incentives for debtholders to take up risky investments. As a result, not all positive net present value projects are financed and the economy experiences credit rationing.[1]

Consider now a project which is financed by informed investors, such as VCs. Informed investors are superior to uninformed investors because they can use more sophisticated incentive mechanisms to induce managerial effort. Reward takes the form of a relative-payoff wage structure with high project returns generating high managerial compensation. Punishment takes the form of project liquidation when a poor signal is observed. Thanks to this more efficient incentive mechanism, a larger number of profitable projects are financed.[2]

However, the threat of such punishment is only credible if investors can be committed ex-ante to liquidation, should a negative signal be observed. Consider the case of a project that requires assets that are specific and therefore are of less value outside the firm than they would be for the generation of future returns within the firm. In this case, committing to project liquidation can be difficult because the assets purchased effectively represent an unrecoverable sunk cost.[3] In such a case, investors are averse to liquidation and would prefer to renegotiate the terms of financing.

We find that when assets are project-specific, an optimal capital structure requires the use of convertible preferred stock.[4] Convertible preferred stock

[1] See Stiglitz and Weiss (1981).

[2] Due to their information advantage, banks are capable of financing a larger number of projects than uninformed investors (Diamond (1984), Fama (1985) and Stiglitz (1985)).

[3] As noted by Hart and Moore (1989) and Hart and Moore (1994), if liquidation hurts not only the firm but also investors, these might prefer to renegotiate a financial contract rather than suffering liquidation losses. On asset specificity see Bolton and Scharfstein (1996).

[4] On the use of convertible securities see Cornelli and Yosha (2003), Gompers and Lerner (2001), Gompers (1995), Hellmann and Manju (2002) and Kaplan and Strömberg (2004).

gives investors the incentives to liquidate when the signal is poor and to continue with the project when the observed signal is good. Conversion into equity takes place when a good signal is observed and expected returns are high. On the contrary, when a bad signal is observed conversion does not take place because investors want to retain the legal protection associated with debt.

Finally, consider the case of a project that is partially financed by the entrepreneur and partially by VCs.[5] An optimum capital structure will now require the VCs to hold convertible preferred stock with senior priority and the entrepreneur to hold common stock. It is necessary that the VCs are senior, so that they have the incentives to monitor and liquidate bad projects. Seniority maximizes the returns of VCs in case of liquidation because they can rely on the cash provided by junior investors.

The rest of the paper is structured as follows. Section 2 provides an example. Section 3 outlines the basic structure of the model. Section 4 discusses project financing in the case of symmetric information, thus achieving First Best as a benchmark case. Section 5 illustrates the case of project financing in the presence of asymmetric information and discusses optimum financing when investors are uninformed and there is entrepreneurial moral hazard. Section 6 examines the case when investors have the ability to monitor and derives the optimum corresponding capital structure. Section 7 discusses the case when projects are partially financed by the entrepreneur and partially by venture capital. Section 8 provides a summary of the main results.

2 An Example

New Company is a private firm that is wholly owned and managed by its founders and wants to undertake an investment that costs \$1ml. The founders only have \$100.000 and need to raise an additional \$900.000 from external investors. The returns of the project are uncertain and will be either \$1.487.500 or \$612.500 depending on the quality of management. Good management requires the founders to provide effort e. The probability of high returns is 0.9 when the firm is well managed ($e = 1$) and 0.1 otherwise ($e = 0$). The private benefits that the founders receive when $e = 0$ amount to \$80.000. The expected returns of the project when the firm is well managed

[5] See Berglöf and von Thadden (1994), Rajan (1992) and Repullo and Suarez (1998) for optimal capital structures with multiple investors.

are

$$0.9 \times \$1.487.500 + 0.1 \times \$612.500 = \$1.400.000$$

and

$$0.1 \times \$1.487.500 + 0.9 \times \$612.500 = \$700.000$$

when it is badly managed. The staging of research is such that the probability distribution of the project's returns becomes known to investors one year after it started. At that stage the firm can be liquidated and the resale value of the assets is \$650.000 or it can be offered to the general public in an IPO. In case of liquidation, the private benefits of the founders reduce to \$50.000.

The company arranges an A round financing with a VC that would provide \$900.000. The VC considers two alternative ways to do so: equity or convertible preferred stock.

Equity Consider first the case in which the VC provides the entire sum in equity. Suppose that one year into the project, the firm appears to be badly managed. Liquidation gives the VC the right to claim \$585.000 which corresponds to 90% of the resale value of the assets, thus incurring a loss of \$900.000−\$585.000 = \$315.00. Alternatively, the VC can bring the project to completion, in which case she expects to receive 90% × \$700.000 = \$630.000, thus incurring a loss of \$900.000 − \$630.000 = \$270.000. As the expected payoffs of continuation are greater than in the case of liquidation, the VC will choose to continue.

From the point of view of the founders the returns from the project when $e = 1$ are

$$10\% \times \$1.400.000 - \$100.000 = \$40.000.$$

When $e = 0$ they expect to get

$$10\% \times \$700.000 - \$100.000 + \$80.000 = \$50.000$$

while in case of liquidation they receive

$$10\% \times \$650.000 - \$100.000 + \$50.000 = \$15.000.$$

Therefore, the founders prefer not to exert effort because their payoff with $e = 0$ is higher than when $e = 1$. Importantly, exerting no effort is riskless for the founders, because liquidation never takes place. Anticipating $e = 0$ the VC refuses to finance the project.

Convertible Preferred Stock Consider now the case of financing through senior convertible preferred stock. The VC stipulates a contract in which she agrees to convert her claims into equity if the firm proceeds to an IPO and to liquidate the firm otherwise. When $e = 0$ the payoffs of the VC change as follows: in case of IPO, the VC holds equity and receives

$$90\% \times \$700.000 - \$900.000 = -\$270.000.$$

While in case of liquidation, the payoff of a VC is $\$650.000 - \$900.000 = -\$250.000$. Therefore, the VC opts for liquidation if $e = 0$.

The payoff of the founders in case of liquidation is now

$$-\$100.000 + \$50.000 = -\$50.000.$$

The difference with the case of equity financing is that liquidation this time takes place when $e = 0$ is revealed. As a result, to avoid liquidation the founders choose $e = 1$ rather than $e = 0$. Convertible preferred stock offers the flexibility to generate state-contingent payoffs which allow the VCs to impose the 'good' equilibrium, in which $e = 1$. Therefore, financing takes place.

3 The Basic Framework

We consider an economy populated by risk-neutral entrepreneurs who are endowed with a project which requires a time t_0 investment of \$1 and which returns $\overline{V}$ if successful and $\underline{V} = \overline{V} - \Delta V < 1 < \overline{V}$ if unsuccessful. The project's probability of success depends on entrepreneurial effort $e \in \{0, 1\}$ and it is equal to π_0 if the entrepreneur makes no effort and to $\pi_1 = \pi_0 + \Delta\pi > \pi_0$ when the entrepreneur exerts effort. The cost of effort for an entrepreneur is $\psi(e) \in \{0, \psi\}$. We assume that projects have negative net present value (NPV) when the entrepreneur does not exert an effort:

$$\pi_0 \overline{V} + (1 - \pi_0) \underline{V} < 1. \tag{1}$$

Entrepreneurs are capital constrained and must finance the \$1 which their project requires. Project financing is provided by investors. There are various types of investors which can be classified according to the type of security that they hold and according to whether they have the ability to monitor their investment or not. We assume that dispersed *shareholders* and *bondholders*

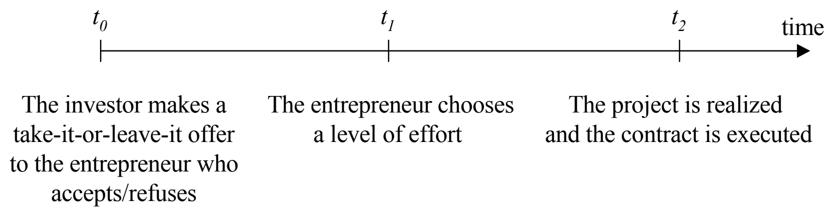

Figure 1: Timing of a Financial Contract

are small individual investors that do not have the ability to monitor. On the contrary, *VCs* and *banks* are large investors that can afford the cost of monitoring.

A *financial contract* $(\overline{r}, \underline{r})$ stipulates the payments made by an entrepreneur to an investor in case her project succeeds or fails, respectively. The phases of a financial contract are illustrate in Figure 1. At time t_0, an investor makes a take-it-or-leave-it offer $\{(\overline{r}, \underline{r}), e\}$ to an entrepreneur which stipulates payments in case of project success, failure and the required entrepreneurial effort. At time t_1, an entrepreneur decides the level of effort. At time t_2, project returns are realized and distributed according to the initial contract $(\overline{r}, r)$.

Given a contract $(\overline{r}, \underline{r})$, an effort level e and a cost of effort $\psi(e)$, an entrepreneur's expected utility is

$$U(\bar{r}, \underline{r}, e) \equiv \pi(e)\left(\overline{V} - \bar{r}\right) + (1 - \pi(e))\left(\underline{V} - \underline{r}\right) - \psi(e), \tag{2}$$

where $\pi(e)$ is π_1 if an entrepreneur makes an effort and π_0 if he does not. The expected income of an investor is

$$I(\bar{r}, \underline{r}, e) \equiv \pi(e)\,\overline{r} + (1 - \pi(e))\,\underline{r} - 1. \tag{3}$$

If an entrepreneur does not run her project, he gets zero which is her reservation utility. Typically an entrepreneur's effort decision will be unobservable so that there is a moral hazard problem between her and investors. In the following case we establish the first best effort decision in the case where effort is observable and contractible.

4 Observable Effort

In this section we derive the benchmark model when effort is observable and thus contractible. This benchmark model defines First Best. We assume that contracts upon effort are costlessly enforceable. An investor is willing to finance a project when her participation constraint is satisfied which requires

$$I\left(\bar{r}, \underline{r}, e\right) \geq 0. \qquad PC_I$$

We assume that entrepreneurs are protected by limited liability in every state of the world which is equivalent to saying that an entrepreneur's payoff satisfies

$$\overline{V} \geq \bar{r} \qquad LLu$$

and

$$\underline{V} \geq \underline{r}. \qquad LLd$$

An entrepreneur is willing to participate in a project only when her participation constraint is satisfied, i.e. her utility must be such that

$$U\left(\bar{r}, \underline{r}, 1\right) = \pi_1\left(\overline{V} - \bar{r}\right) + \left(1 - \pi_1\right)\left(\underline{V} - \underline{r}\right) - \psi \geq 0 \qquad PC_E$$

We can use constraints LLu through PC_E to identify the financial contract that maximizes the returns of an investor. This is achieved by choosing values of $\bar{r}$, $\underline{r}$ and e for which an investor's return are highest. The choice of e is dictated by our assumptions on the project's returns. Equation (1) implies that a time t_0 contract must stipulate that $e = 1$. Furthermore, since by assumption an investor has all of the time t_0 bargaining power, he can minimize costs by keeping the entrepreneur at her reservation utility. Therefore, the optimal choice of $\bar{r}$ and $\underline{r}$ is such that equation PC_E binds and $e = 1$.

At First Best there are infinite contracts which achieve the optimum because any pair $(\bar{r}, \underline{r})$ which satisfies conditions PC_E, LLu and LLd defines an optimal contract. For each pair $(\bar{r}, \underline{r})$ the payoffs of investor and entrepreneur change across the two states of the world. The returns that accrue to an investor over the different states characterize the type of contract used to finance the project. For example, consider a financial contract in which the payoff of an investor in the upper state is $\overline{r} = \overline{V}$. In order to be accepted by an entrepreneur, a contract must satisfy condition PC_E from which we derive that the payoff of an investor in the low state is $\underline{r} = \underline{V} - \frac{\psi}{1-\pi_1}$. In this contract an investor appropriates all returns in the high state and bears all the costs in the low state. In such contract, the investor holds common stock and the entrepreneur is merely an employee.

An alternative contract is one in which an investor receives $\bar{r} = \overline{V} - \frac{\psi}{\pi_1}$ in the high state and $\underline{r} = \underline{V}$ in the low state. Such contract satisfies condition PC_E and is therefore accepted by an entrepreneur. The payoffs identify a debt contract because an investor's returns are capped in the high state and equal to the residual value of the project in the low state. Therefore, in this contract the investor holds debt and the entrepreneur holds equity.

These results are illustrated in Figure 2. The straight downward sloping lines respectively represent the entrepreneur's and investor's participation constraints, PC_E and PC_I. Both curves are downward sloping lines because $\bar{r}$ and $\underline{r}$ are regarded as substitutes by investors and entrepreneurs. More precisely, $\bar{r}$ and $\underline{r}$ are considered 'bads' by an entrepreneur and 'goods' by an investor. An entrepreneur's participation constraint is satisfied at all points below the line $U(\bar{r}, \underline{r}, 1) = 0$; while an investor's participation constrains is satisfied at all points above the line $I(\bar{r}, \underline{r}, 1) = 0$. Define $NPV = \pi_1 \overline{V} + (1 - \pi_1) \underline{V} - 1$. Contracts that lie above the investor's participation constraint have a positive NPV. The optimum contract lies on an entrepreneur's participation constraint and within the box $\underline{V}\overline{V}$. An investor is indifferent between all of the contracts on the line segment AA' and will therefore choose one of these. Contract A identifies pure equity financing. Contract A' identifies the case of pure debt financing. Any other point on the segment between A and A' identifies the case of equity financing with some shares owned by the entrepreneur.

At the optimum an investor's expected profit equal $\pi_1 \overline{V} + (1 - \pi_1) \underline{V} - \psi - 1$, so that at First Best investors entirely internalize the cost of effort. A project will therefore be financed only when

$$NPV \geq \psi,$$

i.e. when the NPV of the project covers the cost of entrepreneurial effort.

In summary, a First Best contract leaves the entrepreneur at her reservation utility and investors are indifferent between financing a project with equity or debt. These results provide a restatement of the first proposition of Modigliani and Miller (1958) on the irrelevancy of a firm's capital structure.

5 Uninformed Investors with Moral Hazard

In this section we consider the case of unobservable effort. As a result of unobservability, effort is not contractible and entrepreneurial moral hazard arises. For the moment, we restrict our analysis to individual investors which do not have the ability to monitor. We investigate how these investors maximize their returns under moral hazard.

Firstly, effort cannot be explicitly included in a financial contract which now takes the form $(\overline{r}, \underline{r})$. Secondly, since by equation (1) investors prefer $e = 1$, to induce effort a contract must satisfy the following entrepreneur's incentive constraint,

$$\pi_1 \left(\overline{V} - \overline{r}\right) + (1 - \pi_1) \left(\underline{V} - \underline{r}\right) - \psi \geq \pi_0 \left(\overline{V} - \overline{r}\right) + (1 - \pi_0) \left(\underline{V} - \underline{r}\right). \quad IC$$

The incentive constraint simplifies to

$$\overline{V} - \overline{r} \geq \underline{V} - \underline{r} + \frac{\psi}{\Delta\pi}. \tag{4}$$

Condition (4) shows that an incentive compatible contract requires an entrepreneur's payoff to be larger in the in the high state than in the low state. From the perspective of an investor, profit maximization can be formally written as

$$\max_{0 \leq \overline{r} \leq \overline{V}, 0 \leq \underline{r} \leq \underline{V}} I\left(\overline{r}, \underline{r}\right)$$

subject to IC and PC_E.

The following Lemma provides the solution to this maximization which is illustrated in Figure 2.

Lemma 1 ***(Debt as an incentive compatible contract)*** *When effort is not observable, constraints LLd and IC bind at the optimum yielding the following Second Best returns for an investor,*

$$\overline{r}^{SB} = \overline{V} - \frac{\psi}{\Delta\pi},$$
$$\underline{r}^{SB} = \underline{V}.$$

Proof. See Appendix. ■

As in Jensen and Meckling (1976), to provide incentives an optimum contract rewards the entrepreneur in the high state with a compensation $\frac{\psi}{\Delta\pi}$.

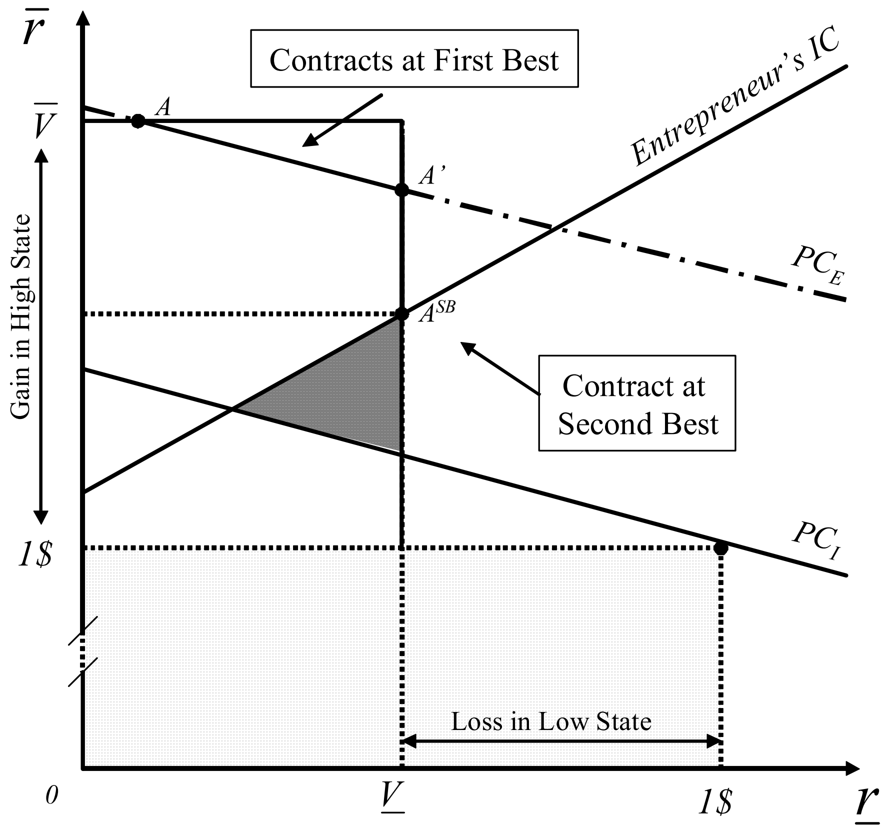

Figure 2: The diagram illustrates the financing problem of an entrepreneurial firm both when effort is observable (First Best) and when there is moral hazard (Second Best). First Best is achieved by any contract that lies on the segment AA'. The contract in A' identifies the case of pure debt financing. Any other point on the segment between A and A' identifies the case of equity financing with some shares owned by the entrepreneur. At Second Best, the only feasible contracts lie below IC and to the left of $\underline{V}$, in the shaded triangular area. A Second Best contract is A^{SB} in which case the firm is entirely debt financed.

The difference between the payoff of an entrepreneur in the high and low state identifies a *relative-payoff incentive mechanism.* Contract $\left(\overline{r}^{SB}, \underline{r}^{SB}\right)$ characterizes debt: investors receive only part of the gains in the high state and are residual claimants in the low state.

Financing Condition for Uninformed Investors By inserting $\left(\underline{r}^{SB}, \overline{r}^{SB}\right)$ into the investor's participation constraint, we find that at Second Best project financing occurs only when

$$NPV \geq \frac{\pi_1 \psi}{\Delta\pi} \geq \psi.$$

The difference $\frac{\pi_1 \psi}{\Delta\pi} - \psi$ represents the rent of an entrepreneur under moral hazard. The project financing condition is harder to satisfy at Second Best than at First Best and some projects that are financed if effort is observable, are not financed under moral hazard. We conclude that at Second Best the economy experiences credit rationing because some positive NPV projects are not financed due to information costs. Consider the following example. Suppose that $\psi = 0.1$, $\pi_1 = 0.7$ and $\pi_0 = 0.4$. At First Best a project is financed when $NPV \geq 10\%$. At Second Best a project is financed only when $NPV \geq 23.3\%$.

6 Informed Investors with Moral Hazard

In this section we examine project financing when investors, such as VCs and banks, have the ability to monitor their investments. We assume that investments are monitored before they reach completion and that monitoring costs c. Through monitoring an investor acquires a signal $\tilde{\sigma}$ which depends on the entrepreneur's effort and belongs to the set $\Sigma = \{\sigma_0, \sigma_1\}$. In the context of stage financing, a good signal can be interpreted as reaching a preset milestone. The matrix below gives the probabilities of each signal σ_i for different levels of entrepreneurial effort

Signal/Effort	$e = 0$		$e = 1$
σ_1	$1 - p$	$<$	$1 - p_1$
σ_0	p	$>$	p_1

For simplicity we assume that $p_1 = 0$ which implies that the monitoring technology allows only for Type I and not for Type II errors. We assume that informed investors have the right to liquidate a project before cash flows are realized.[6] More precisely, investors can liquidate upon observing σ. Liquidating a project before completion is costly for investors when the project requires specific assets which have little resale value. When investors liquidate project specific assets, they only recover a percentage α of the original investment. In this context, α can be interpreted as the market value of collateral and $1-\alpha$ represents the dead-weight loss of liquidation.

An entrepreneur's incentive constraint is then given by the following condition,

$$\pi_1\left(\overline{V}-\overline{r}\right)+(1-\pi_1)\left(\underline{V}-\underline{r}\right)-\psi \geq (1-p)\left[\pi_0\left(\overline{V}-\overline{r}\right)+(1-\pi_0)\left(\underline{V}-\underline{r}\right)\right]. \quad ICm$$

Condition ICm is easier to satisfy than IC. Not exerting effort is now less attractive for an entrepreneur because with probability p the project is liquidated. As the monitoring technology becomes more efficient, i.e. as p increases, condition ICm becomes less stringent.[7]

When investors have the ability to monitor, they can match a relative-payoff incentive mechanism with a *liquidation incentive mechanism* which relies on punishing an entrepreneur by liquidating the project. Entrepreneurs always prefer project completion to early liquidation because in case of liquidation their payoff is always zero. When combined, the two incentive mechanisms operate as a 'carrot and stick'. While the relative-payoff acts as a carrot for the entrepreneur because it provides a prize for generating high returns, the threat of liquidation plays the role of a stick by providing a punishment.

The timing of contracting with monitoring is represented in Figure 3. At time t_0, an investor makes a take-it-or-leave-it contract offer $(\overline{r},\underline{r})$ to an entrepreneur which stipulates payments in case of project success, failure

[6] If uninformed investors were given the option to liquidate, they would never do so because uninformed investors do not acquire new information during the life of the project.

[7] When investors have the ability to monitor, an entrepreneur's incentive constraint is represented by a straight line which crosses condition LLd at $\overline{V}-\frac{\psi}{\Delta\pi_p}$. The incentive constraint has positive slope if $p<\frac{\Delta\pi}{1-\pi_0}$ and negative if $p>\frac{\Delta\pi}{1-\pi_0}$. When $p=1$, i.e. technology is perfectly efficient, the incentive and participation constraints are identical and effort is always observable. On the contrary, when $p=0$ the monitoring technology is completely inefficient and condition ICm simplifies to IC, as in the case when effort is not observable.

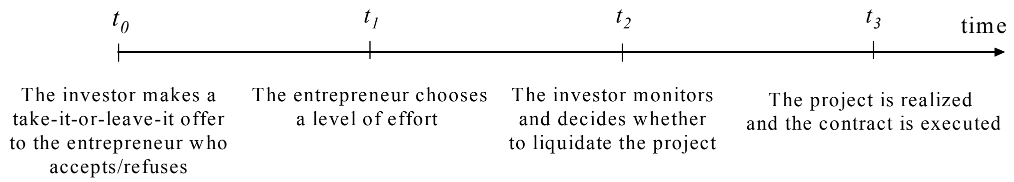

Figure 3: Timing of contracting with monitoring and liquidation

and liquidation. At time t_1, the entrepreneur chooses the level of effort. At time t_2, monitoring takes place and liquidation might follow. The contract is executed at time t_3.

For a liquidation threat to be credible, the expected returns of an investor upon observing σ_0 must be smaller than what he would get by liquidating the project. Otherwise, upon observing σ_0 an investor always prefers to renegotiate the contract with the entrepreneur. A contract is renegotiation-proof if the following condition is satisfied

$$\alpha \geq \pi_0 \overline{r} + (1 - \pi_0)\underline{r}. \qquad CC$$

Condition CC identifies an investor's *commitment constraint*. When the constraint is satisfied, upon observing σ_0 an investor chooses to liquidate the project. Asset specificity plays an important role here. When assets have little value outside the project (low α), it is difficult for an investor to credibly commit to liquidate the investment. On the contrary, when assets are not firm specific and can be easily resold (high α), early project liquidation represents a credible threat for an entrepreneur.

To maximize profits investors must choose a financial contract which maximizes their returns from the investment and gives the entrepreneur an incentive to exert effort. If such contract is to rely on monitoring, it must then also respect an investor's commitment constraint. More formally, an investor profit maximization can be written as

$$\max_{0 \leq \overline{r} \leq \overline{V}, 0 \leq \underline{r} \leq \underline{V}} I\left(\overline{r}, \underline{r}\right)$$

subject to CC, ICm and PC_E.

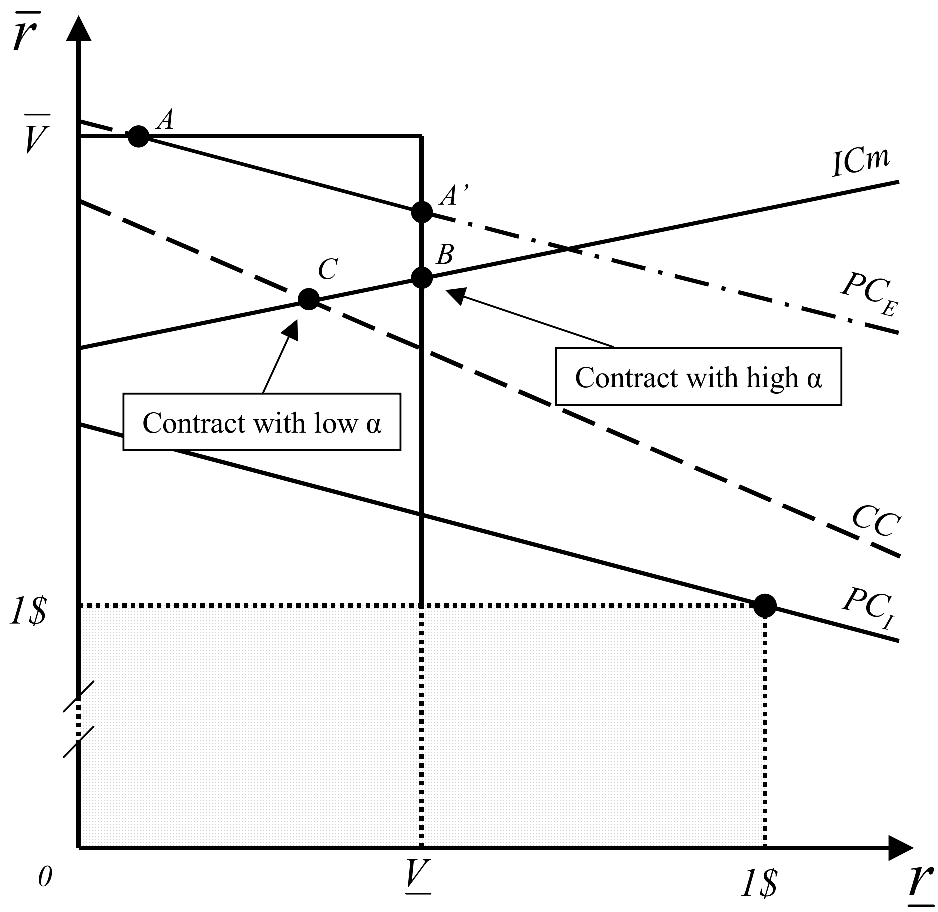

Figure 4: The diagram illustrates an investor's profit maximization when investments can be monitored. Feasible contracts must be in the box $\underline{V}\overline{V}$ and below conditions ICm and CC. When the efficiency of the monitoring technology increases (higher p) condition ICm becomes less stringent, thus moving upwards and becoming shallower. When assets are not project-specific (high α) condition CC does not bind and the optimum is identified by B. Financing takes place via a pure debt contract. When assets are project-specific (low α), condition CC binds, the optimum is in C and financing requires the use of convertible-preferred stock. In this case entrepreneurs hold equity with a vesting option.

The following Lemma provides a solution to an investor's profit maximization. Figure 4 provides an illustration.

Lemma 2 ***(Preferred-convertible Stock and Common Stock with Vesting)*** *Let* $V_0 \equiv \pi_0 \left(\overline{V} - \frac{\psi}{\Delta\pi_p}\right) + (1-\pi_0)\underline{V}$ *and* $\Delta\pi_p = \pi_1 - (1-p)\pi_0$, *then, conditional upon monitoring, the optimal contract depends on* p *and* α *as follows:*

- *if* $\alpha > V_0$ *the optimum contract is* $\overline{r}_B = \overline{V} - \frac{\psi}{\Delta\pi_p}$ *and* $\underline{r}_B = \underline{V}$*;*
- *if* $p > \frac{\Delta\pi}{1-\pi_0}$ *and* $V_0 - \frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{p-\Delta\pi_p} \leq \alpha \leq V_0$ *or if* $p < \frac{\Delta\pi}{1-\pi_0}$ *and* $\alpha \leq V_0$ *the optimum contract is*

$$\begin{aligned} \overline{r}_C &= \overline{V} - \tfrac{\psi}{\Delta\pi_p} + (V_0 - \alpha)\tfrac{p-\Delta\pi_p}{\Delta\pi} \\ \underline{r}_C &= \underline{V} - (V_0 - \alpha)\tfrac{\Delta\pi_p}{\Delta\pi} \end{aligned}$$

- *if* $p > \frac{\Delta\pi}{1-\pi_0}$ *and* $\alpha \leq V_0 - \frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{p-\Delta\pi_p}$ *the optimum contract is* $\overline{r}_D = \overline{V}$ *and* $\underline{r}_D = \frac{\alpha - \pi_0\overline{V}}{1-\pi_0}$.

Proof. See Appendix. ■

Lemma 2 illustrates the relationship between asset specificity and the optimum contract. When assets are not project specific (high α), the optimum contract is $(\overline{r}_B, \underline{r}_B)$, i.e. a debt contract. As common banking practice suggests, debt is optimal when there is sizeable collateral. When assets are project specific (low α), the optimum contract is $(\overline{r}_C, \underline{r}_C)$. The cash flows of this contract characterize a situation in which both investors and entrepreneurs hold equity. In this case, optimal contracting requires investors to hold convertible-preferred stock and entrepreneurs to hold common stock with a vesting option. When the preset milestones are not met (σ_0), the entrepreneur's shares do not vest and the investors claims are not converted. Investors, thus, hold a position of straight debt and entrepreneurs have no rights to claim. Projects are liquidated before completion and their entire residual value (α) goes to the VCs. On the contrary, when the preset milestones are reached (σ_1), the convertible-preferred stock is converted into common stock and the entrepreneur's shares vest. In this case, both entrepreneur and VCs hold equity, as in contract $(\overline{r}_C, \underline{r}_C)$.

Financing Condition for Informed Investors We examine now how monitoring affects project financing and show that a larger number of positive NPV projects are financed when monitoring is possible. At contract $(\overline{r}_C, \underline{r}_C)$ the ability to monitor an investment increases an investor's profits if $I(\overline{r}_C, \underline{r}_C) \geq I(\overline{r}_{A^{SB}}, \underline{r}_{A^{SB}})$, a condition that can be written as

$$\underbrace{\frac{\psi\pi_1}{\Delta\pi} - \frac{\psi\pi_1}{\Delta\pi_p}}_{\text{expected reduction in moral hazard rents}} \geqslant c + \underbrace{(1-p)(V_0-\alpha)}_{\text{cost of commitment}}. \tag{5}$$

The terms $\frac{\psi\pi_1}{\Delta\pi}$ and $\frac{\psi\pi_1}{\Delta\pi_p}$ are respectively what uninformed and informed investors give to entrepreneurs as incentive compensations. Notice that $\frac{\psi\pi_1}{\Delta\pi} \geq \frac{\psi\pi_1}{\Delta\pi_p}$. Therefore, the left hand side of condition (5) gives us the amount of money that can be saved by informed investors on entrepreneurial compensations. The right hand side of condition (5) represents the costs required to monitor an investment. The term $(1-p)(V_0-\alpha)$ refers specifically to the cost of commitment (*bonding cost*). As this cost decreases with α, it is ex-ante optimum to give investors liquidation rights that are not smaller than α. In other words, in case of liquidation entrepreneurs should receive zero. In the special case when $\alpha \geq V_0$, the only cost of monitoring is simply given by c. If $c = 0$, the ability to monitor makes an informed investor always better off than an uninformed one.

The financing condition for an informed investor is as follows,

$$NPV \geq \min\left[\frac{\pi_1\psi}{\Delta\pi}, \frac{\pi_1\psi}{\Delta\pi_p} + c + (V_0-\alpha)(1-p)\right]. \tag{6}$$

The project financing condition for informed investors is slacker than the analogous condition for uninformed investors, thus indicating that a larger number of projects will be financed when investors are informed. Therefore, we conclude that there is less credit rationing in the economy when investors have the ability to monitor an investment. Consider the example of the previous section. Suppose that $\alpha > V_0$, $p = 0.5$ and $c = 0.01$. Then, the financing condition requires $NPV \geq \min[0.233, 0.15] = 15\%$ rather than $NPV \geq 23.3\%$ as for uninformed investors.

In sum, the existence of informed investors reduces credit rationing. Informed investors finance a larger number of projects than uniformed investors, relying on two types of financial contracts. Pure debt contracts are employed when assets are not project-specific. A mix of convertible-preferred stock and entrepreneurial share-ownership with vesting characterizes the optimum financial contract when assets are project-specific.

7 The Founders' Investment

Rename what we have so far referred to as entrepreneurs with the term founders. We now examine the case when the founders contribute with their own cash to the initial financing of a project. Suppose that the founders' contribution is $0 \leq \tau \leq 1$ of the required investment and that $1-\tau$ is provided by VCs. We assume that in case of liquidation the VCs receive $\beta\alpha$ and the founders $(1-\beta)\,\alpha$ with $0 \leq \beta \leq 1$. A contract is renegotiation proof only if the following condition is satisfied,

$$\alpha\beta \geq \pi_0\overline{r} + (1-\pi_0)\underline{r}. \qquad CC'$$

VCs are willing to finance a project and monitor when $I\left(\bar{r},\underline{r}\right) \geq c-\tau$ and the founders participate with their own capital only if $U\left(\bar{r},\underline{r}\right) \geq \tau$. In the appendix we show that the founders' contribution makes the cost of commitment for the VCs equal to $(V_0-\alpha\beta-\tau)\,(1-p)$, which is a decreasing function of τ. For a VC, the founders' participation lowers commitment costs, only when

$$\tau \geq \alpha\,(1-\beta) \tag{7}$$

i.e. when the capital provided by the founders is greater than what the founders will receive in case of early liquidation. The share β of liquidation cash flows depends on seniority. When VCs are senior, they receive a cash flow $\alpha\beta = 1-\tau$ if $\alpha > 1-\tau$ and $\alpha\beta = \alpha$ otherwise, i.e.

$$\beta_{Sen}\,(\tau) = \min\left[1, \frac{1-\tau}{\alpha}\right].$$

When VCs are junior, they receive a cash flow $\alpha\beta = \alpha - \tau$ if $\alpha > \tau$ and 0 otherwise, i.e.

$$\beta_{Jun}\,(\tau) = \max\left[0, \frac{\alpha-\tau}{\alpha}\right].$$

To minimize commitment costs, we must solve

$$\min_{\tau}\,(V_0 - \alpha\beta\,(\tau) - \tau)\,(1-p).$$

subject to (7).

The following Lemma provides the solution to the minimization.

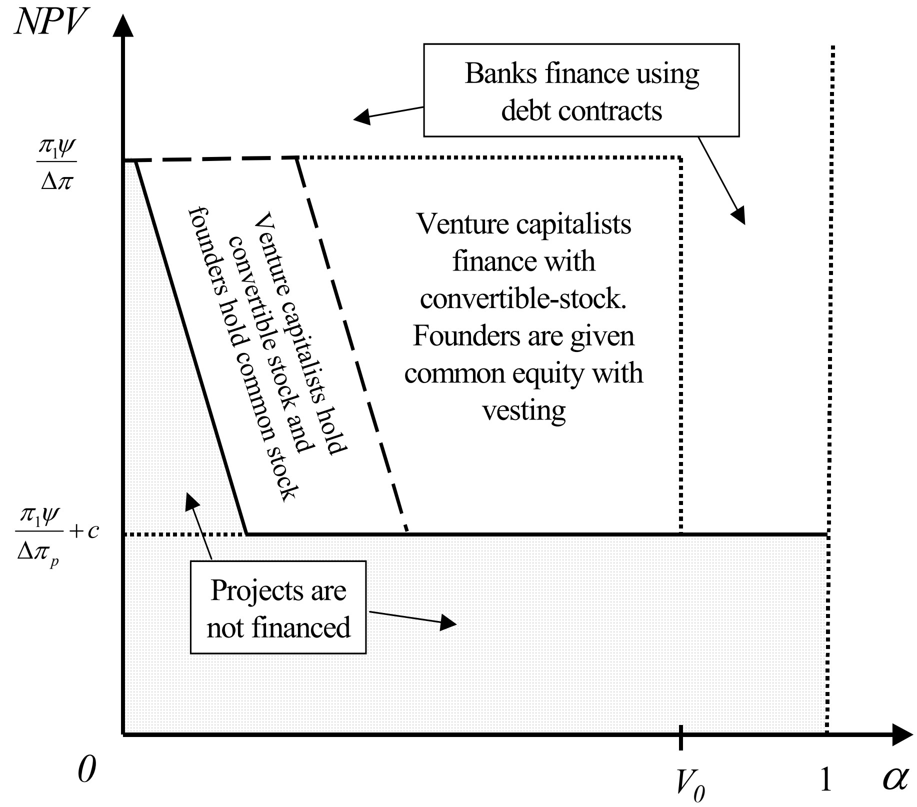

Figure 5: The diagram illustrates the conditions for project financing for different values of NPV and α. A project that has either high NPV or high α will be financed by a bank with a debt contract. Projects with low NPV and high α are financed by venture capitalists with convertible-preferred stock. Projects with low NPV and low α require an initial investment by the founders.

Lemma 3 ***(Seniority and Minimum Founders' Investment)*** *Commitment costs are minimized when VCs are senior and the founders provide an amount of capital $\tau = 1 - \alpha$.*

Proof. See Appendix. ■

The Lemma contains two main results. First, in an optimum contract, VCs are senior. This result is driven by the fact that $\beta_{Sen}(\tau) \geq \beta_{Jun}(\tau)$. Seniority lowers commitment costs because VCs are insured by the founders' capital which acts as a "cash cushion". If the founders' contribution is large ($\tau \geq 1 - \alpha$), VCs are perfectly insured against a liquidation loss. Second, when α decreases the founders required contribution increases. The relationship between τ and α is linear and negative. Figure 5 shows how the optimum financial contract varies for different values of NPV, α and τ. For example, a project has an initial cost of 1 and has expected returns equal to 0.8 if $e = 0$. In the absence of founders' capital, a financial contract is renegotiation proof only if $\alpha \geq 0.8$. Suppose now that the founders contribute with $\tau = 0.5$ and hold junior claims. Then, a financial contract is renegotiation proof if $\alpha \geq 0.5$. This implies that positive NPV projects with $0.5 \leq \alpha \leq 0.8$ are only financed if the founders invest their own money.

Figure 6 provides a summary of the expected cash flows for VCs and founders for different expected project returns. The expectations used here are conditional upon observing a signal about entrepreneurial effort at time t_2. The diagram on top illustrates the expected returns for VCs that hold senior convertible-preferred stock. Upon monitoring, projects with low expected cash flows are liquidated. If the liquidation value of the project is smaller than $1 - \tau$, the VCs claim the entire liquidation value and make a loss equal to $\alpha - (1 - \tau)$. On the contrary, if the liquidation value of the project is greater than $1 - \tau$, the VCs receive only he value of their original investment. When the observed signal is positive, conversion takes place and the VCs share in the appreciation of the value of equity. The bottom diagram illustrates the expected returns for the founders. As junior investors the founders receive zero in case of liquidation. Only once the VCs are fully compensated, the founders have claiming rights over the remaining assets. In case of conversion, the founders are entitled to a share of the final project returns.

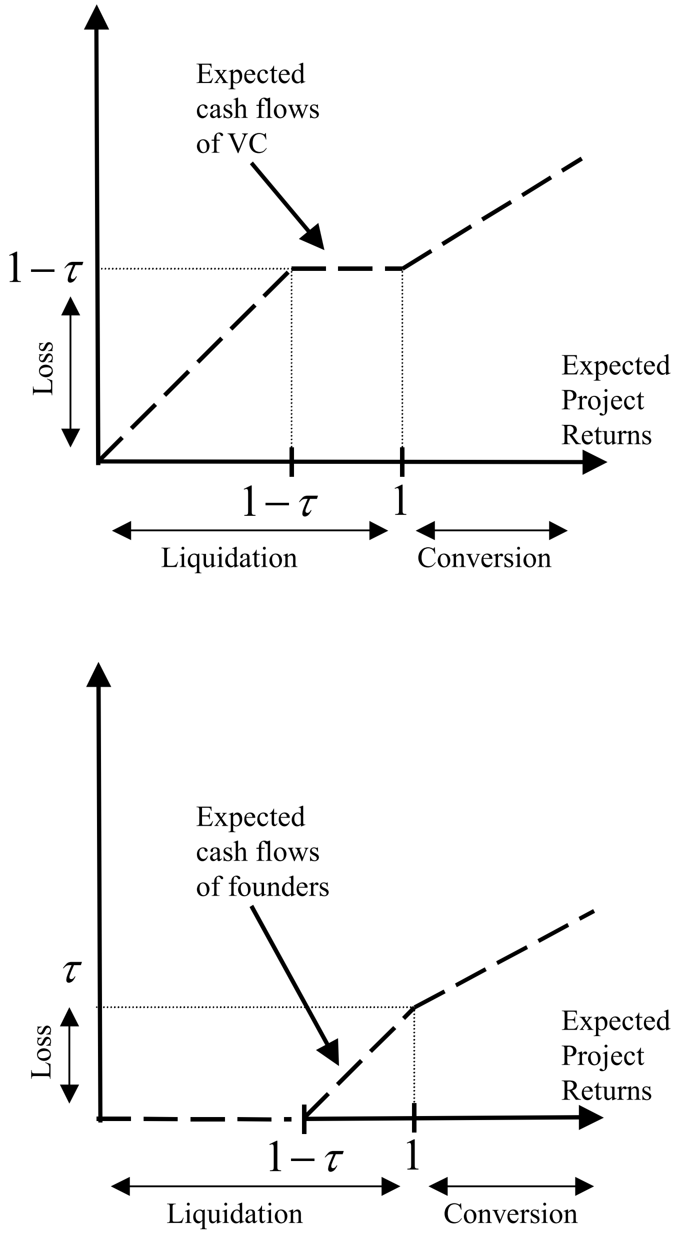

Figure 6: Summary of Cash Flows

8 Conclusions

This paper offers an explanation for the use of convertible-preferred stock in venture capital financing. This type of security maximizes the incentives for investors to monitor and liquidate projects that perform poorly. In this context, liquidation is a tool used by VCs to enforce managerial discipline. The threat of liquidation helps motivate entrepreneurs to exert maximum effort.

Unfortunately, liquidation is not always useful in providing incentives. The threat of liquidation is empty when entrepreneurs anticipate ex-post renegotiation following low results. The incentives for an investor to renegotiate are particularly strong if the resale value of the assets is low. This is often the case when an investment requires project-specific assets. In this case, an investor might be better off by continuing a poorly performing project than liquidating.

The difficulty for investors to commit ex-ante to ex-post inefficient liquidation underlines the need for a properly designed allocation of cash flows. This commitment problem can be partially solved only by making VCs senior and by increasing the contribution of the founders to the initial investment. Indeed, when the founders provide a sizeable share of the initial investment, VCs can rely on a 'cash cushion' to absorb the potential losses of liquidation.

9 Appendix

Proof of Lemma (1) First show that the entrepreneur's incentive constraint is always more stringent than her participation constraint. To prove this point, it suffices to observe that the right hand side of condition IC is greater than zero when $\overline{r} \geq \overline{V}$ and $\underline{r} \geq \underline{V}$. PC_E can then be omitted. Cost minimization implies that IC binds at the optimum, thus yielding

$$\overline{r} = \Delta V + \underline{r} - \frac{\psi}{\Delta\pi}. \tag{8}$$

In order to maximize returns, an investors sets $\underline{r} = \underline{V}$. From equation (8) we then obtain $\overline{r} = \overline{V} - \frac{\psi}{\Delta\pi}$.

Proof of Lemma (2) First show that the entrepreneur's incentive constraint is always more stringent than her participation constraint. To prove this point, it suffices to observe that the right hand side of condition ICm is greater than zero when $\overline{r} \geq \overline{V}$ and $\underline{r} \geq \underline{V}$. PC_E can then be omitted. ICm and CC always cross and their intersection takes place at

$$\begin{aligned} \overline{r}' &= \overline{V} - \tfrac{\psi}{\Delta\pi_p} + (V_0 - \alpha)\,\tfrac{p-\Delta\pi_p}{\Delta\pi}, \\ \underline{r}' &= \underline{V} - (V_0 - \alpha)\,\tfrac{\Delta\pi_p}{\Delta\pi} \end{aligned}$$

with $V_0 \equiv \pi_0\left(\overline{V} - \frac{\psi}{\Delta\pi_p}\right) + (1-\pi_0)\underline{V}$ and $\Delta\pi_p \equiv \pi_1 - \pi_0\,(1-p) \geq \Delta\pi$. Conditions LLu and LLu are respectively satisfied when $\overline{r}' \leq \overline{V}$ and $\underline{r}' \leq \underline{V}$. Using the definitions of $\overline{r}'$ and $\underline{r}'$, we identify six possible cases:

1. if $p > \frac{\Delta\pi}{1-\pi_0}$ and $\alpha \leq V_0 - \frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{p-\Delta\pi_p}$ then $\overline{r}' \geq \overline{V}$ and $\underline{r}' \leq \underline{V}$.
2. if $p > \frac{\Delta\pi}{1-\pi_0}$ and $V_0 - \frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{p-\Delta\pi_p} \leq \alpha \leq V_0$ then $\overline{r}' \leq \overline{V}$ and $\underline{r}' \leq \underline{V}$;
3. if $p > \frac{\Delta\pi}{1-\pi_0}$ and $\alpha \geq V_0$ then $\overline{r}' \leq \overline{V}$ and $\underline{r}' \geq \underline{V}$;
4. if $p < \frac{\Delta\pi}{1-\pi_0}$ and $\alpha \leq V_0$ then $\overline{r}' \leq \overline{V}$ and $\underline{r}' \leq \underline{V}$;
5. if $p < \frac{\Delta\pi}{1-\pi_0}$ and $V_0 \leq \alpha \leq V_0 + \frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{\Delta\pi_p - p}$ then $\overline{r}' \leq \overline{V}$ and $\underline{r}' \geq \underline{V}$;
6. if $p < \frac{\Delta\pi}{1-\pi_0}$ and $\alpha \geq V_0 + \frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{\Delta\pi_p - p}$ then $\overline{r}' \geq \overline{V}$ and $\underline{r}' \geq \underline{V}$;

In case 1, the constraints that bind are CC and LLu and the optimum is $\overline{r}_D = \overline{V}$ and $\underline{r}_D = \frac{\alpha - \pi_0\overline{V}}{1-\pi_0}$. In cases 2 and 4 , CC and ICm are the constraints that bind and the optimum is $\overline{r}_C = \overline{r}'$ and $\underline{r}_C = \underline{r}'$. In cases 3, 5 and 6, ICm and LLd are the only constraints that bind and the optimum is $\overline{r}_B = \overline{V} - \frac{\psi}{\Delta\pi_p}$and $\underline{r}_B = \underline{V}$.

Proof that the costs of commitment equals $(V_0 - \alpha\beta - \tau)\,(1-p)$ The founders' incentive constraint is given by the following condition,

$$\begin{aligned} &\pi_1\left(\overline{V} - \overline{r}\right) + (1-\pi_1)\left(\underline{V} - \underline{r}\right) - \tau - \psi \geq \\ &\qquad (1-p)\left[\pi_0\left(\overline{V} - \overline{r}\right) + (1-\pi_0)\left(\underline{V} - \underline{r}\right) - \tau\right]. \quad (ICm') \end{aligned}$$

Rewrite the participation constraint of the founder,

$$\pi_1\left(\overline{V} - \overline{r}\right) + (1-\pi_1)\left(\underline{V} - \underline{r}\right) - \tau - \psi \geq 0.$$

The participation constraint is more stringent than the incentive constraint only if

$$\pi_0\left(\overline{V}-\overline{r}\right)+\left(1-\pi_0\right)\left(\underline{V}-\underline{r}\right)\leq\tau. \tag{9}$$

Given that by assumption $\pi_0\overline{V}+(1-\pi_0)\underline{V}<1$, it is always possible to find a τ which is large enough for (9) to be satisfied. Therefore, when the share of capital provided by the founders is large, First Best is achieved.

Consider the more interesting case when (9) is not satisfied. The incentive constraint binds, the participation constraint is slack and First Best cannot be achieved. Indicate with $\left(\underline{i},\overline{i}\right)$ the loss that the founders will incur respectively in the high and low state. Limited liability for the founders requires that $\overline{V}\geq\overline{i}+\overline{r}$ and $\underline{V}\geq\underline{i}+\underline{r}$ with $\pi\left(e\right)\overline{i}(1-\pi\left(e\right))\underline{i}=\tau$. ICm' and CC' always cross and for any given $\overline{i}$ and $\underline{i}$ their intersection takes place at

$$\begin{array}{c}\overline{r}''=\overline{V}-\overline{i}-\frac{\psi}{\Delta\pi_p}+\left(V_0'-\alpha\beta\right)\frac{p-\Delta\pi_p}{\Delta\pi},\\ \underline{r}''=\underline{V}-\underline{i}-\left(V_0'-\alpha\beta\right)\frac{\Delta\pi_p}{\Delta\pi}\end{array}$$

with $V_0'\equiv\pi_0\left(\overline{V}-\overline{i}-\frac{\psi}{\Delta\pi_p}\right)+\left(1-\pi_0\right)\left(\underline{V}-\underline{i}\right)$. Limited liability is satisfied when $\overline{r}''\leq\overline{V}-\overline{i}$ and $\underline{r}''\leq\underline{V}-\underline{i}$. Using the definitions of $\overline{r}''$ and $\underline{r}''$, we identify six possible cases:

1. if $p>\frac{\Delta\pi}{1-\pi_0}$ and $\alpha\beta\leq V_0'-\frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{p-\Delta\pi_p}$ then $\overline{r}''\geq\overline{V}-\overline{i}$ and $\underline{r}''\leq\underline{V}-\underline{i}$.
2. if $p>\frac{\Delta\pi}{1-\pi_0}$ and $V_0'-\frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{p-\Delta\pi_p}\leq\alpha\beta\leq V_0'$ then $\overline{r}''\leq\overline{V}-\overline{i}$ and $\underline{r}''\leq\underline{V}-\underline{i}$;
3. if $p>\frac{\Delta\pi}{1-\pi_0}$ and $\alpha\beta\geq V_0'$ then $\overline{r}''\leq\overline{V}-\overline{i}$ and $\underline{r}''\geq\underline{V}-\underline{i}$;
4. if $p<\frac{\Delta\pi}{1-\pi_0}$ and $\alpha\beta\leq V_0'$ then $\overline{r}''\leq\overline{V}-\overline{i}$ and $\underline{r}''\leq\underline{V}-\underline{i}$;
5. if $p<\frac{\Delta\pi}{1-\pi_0}$ and $V_0'\leq\alpha\beta\leq V_0'+\frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{\Delta\pi_p-p}$ then $\overline{r}''\leq\overline{V}-\overline{i}$ and $\underline{r}''\geq\underline{V}-\underline{i}$;
6. if $p<\frac{\Delta\pi}{1-\pi_0}$ and $\alpha\beta\geq V_0'+\frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{\Delta\pi_p-p}$ then $\overline{r}''\geq\overline{V}-\overline{i}$ and $\underline{r}''\geq\underline{V}-\underline{i}$;

In case 1, the constraints that bind are CC' and the limited liability in the high state and the optimum is $\overline{r}_D'=\overline{V}-\overline{i}$ and $\underline{r}_D=\frac{\alpha\beta-\pi_0\left(\overline{V}-\overline{i}\right)}{1-\pi_0}$. In cases 2 and 4 , CC' and ICm' are the constraints that bind and the optimum is

$\overline{r}_C = \overline{r}''$ and $\underline{r}_C = \underline{r}''$. In cases 3, 5 and 6, ICm' and the limited liability constraint in the low state are the only constraints that bind and the optimum is $\overline{r}'_B = \overline{V} - \overline{i} - \frac{\psi}{\Delta\pi_p}$and $\underline{r}'_B = \underline{V} - \underline{i}$.

The optimum contracts can then be summarized as follows:

- if $\alpha > \frac{V'_0}{\beta}$ the optimum contract is $\overline{r}'_B = \overline{V} - \overline{i} - \frac{\psi}{\Delta\pi_p}$ and $\underline{r}'_B = \underline{V} - \underline{i}$;

- if $p > \frac{\Delta\pi}{1-\pi_0}$ and $\frac{1}{\beta}\left(V'_0 - \frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{p-\Delta\pi_p}\right) \leq \alpha \leq \frac{V'_0}{\beta}$ or if $p < \frac{\Delta\pi}{1-\pi_0}$ and $\alpha \leq \frac{V'_0}{\beta}$ the optimum contract is

$$\overline{r}'_C = \overline{V} - \overline{i} - \frac{\psi}{\Delta\pi_p} + (V'_0 - \alpha\beta)\frac{p-\Delta\pi_p}{\Delta\pi}$$
$$\underline{r}'_C = \underline{V} - \underline{i} - (V'_0 - \alpha\beta)\frac{\Delta\pi_p}{\Delta\pi}$$

- if $p > \frac{\Delta\pi}{1-\pi_0}$ and $\alpha \leq \frac{1}{\beta}\left(V'_0 - \frac{\psi}{\Delta\pi_p}\frac{\Delta\pi}{p-\Delta\pi_p}\right)$ the optimum contract is $\overline{r}_D = \overline{V} - \overline{i}$ and $\underline{r}_D = \frac{\alpha\beta - \pi_0\left(\overline{V}-\overline{i}\right)}{1-\pi_0}$.

At contract $(\overline{r}'_C, \underline{r}'_C)$, the ability to monitor an investment increases an investor's profits if $I(\overline{r}'_C, \underline{r}'_C) \geq I(\overline{r}_{A^{SB}}, \underline{r}_{A^{SB}})$, a condition that can be written as

$$\frac{\psi\pi_1}{\Delta\pi} - \frac{\psi\pi_1}{\Delta\pi_p} \geqslant c + \underbrace{(V_0 - \alpha\beta - \tau)(1-p)}_{\text{cost of commitment with joint financing}}.$$

Proof of Lemma 3 As illustrated in Figure (7), $\beta_{Sen}(\tau) \geq \beta_{Jun}(\tau)$, thus

implying that informed investors must be senior to minimize commitment costs. If $\tau \leq 1 - \alpha$, the objective function equals $(V_0 - \alpha - \tau)(1-p)$ and has a minimum in $\tau = 1 - \alpha$. In this case $\beta = 1$ and condition (7) simplifies to $\tau \geq 0$ which is always satisfied. If $\tau \geq 1 - \alpha$, the objective function equals $(V_0 - 1)(1-p)$ which is constant. In this case, condition (7) requires $\alpha \leq 1$ which is true by assumption. By comparing the two cases, we find that the optimum is in $\tau = 1 - \alpha$.

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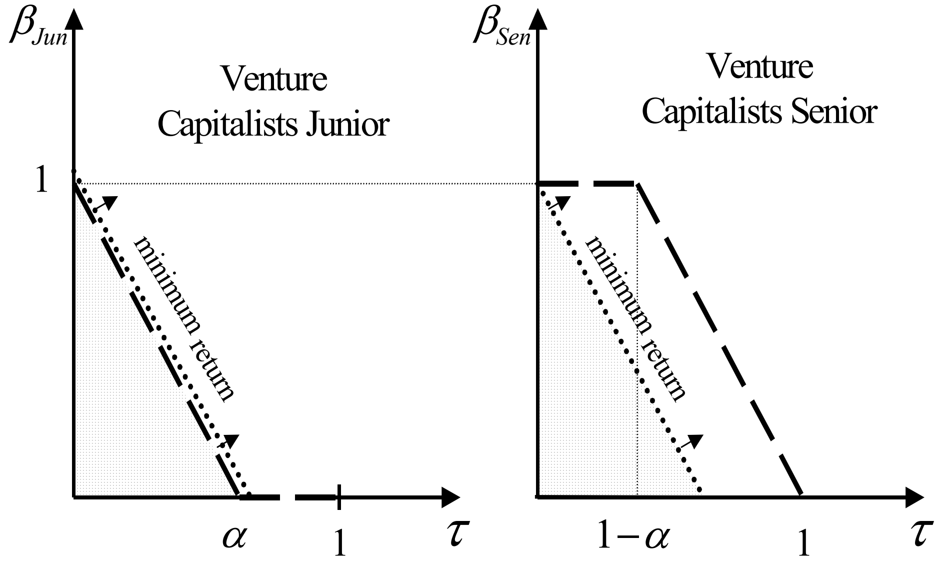

Figure 7: In both diagrams, the value on the vertical axis represents the share of liquidated assets that goes to venture capitalists. In the left diagram, the dashed line represents $\beta_{Jun}(\tau)$. Venture capitalists receive zero only when $\tau \geq \alpha$. In the right diagram, the dashed line represents $\beta_{Sen}(\tau)$. Venture capitalists receive strictly more than zero when $\tau < 1$, i.e. as long as they provide some financing. In both diagrams, condition (7) is satisfied only when β lies above the dotted line.

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