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Abstract

In this paper we study the conflict of interests between limited partners (LPs) and a general partner (GP) in a VC fund with a limited life-span. LPs commit money for investment in risky projects, while the GP selects projects and provides unobservable advisory effort (monitoring) for each project. We assume that GP privately observes projects' quality and the estimated time to exit and decides which projects to continue. The limited time horizon of the fund forces the GP to dispose of all the unfinished projects at that point. This necessity combined with the informational asymmetry of the VC lead to inefficient decisions by the GP during the intermediate investment stages. These suboptimal decisions include continuations of bad projects as well as write-offs of good projects.

This paper presents a two-period model that identifies the source and extent of this inefficiency and analyses possible equilibria. We show that when unfinished projects are fairly priced, bad projects are always continued. We also show that under a wide range of parameter values good projects with somewhat longer expected time to exit may be discontinued as well, since GP may optimally decide not to invest his monitoring effort in them. We propose several contractual amendments to alleviate the problem. First, we show that reduction of the GP's stake in all the unfinished projects can significantly weaken his incentives to prolong bad projects. This in turn may induce the GP to put effort in the "delay prone" good projects. An outright termination of all unfinished projects, as practiced by some VC funds, is similar in nature, but leads to suboptimal early write-offs of some good projects. Next, we show that allocating non-vested cash (but not decision) rights in the unfinished projects to GP has similar beneficial effects.

JEL classification: G24, G32

I Introduction

While accounting for a relatively modest part of overall corporate investments, Venture Capital (VC) investment plays a major role in financing high risk - high return projects, some of which later become the leading economic drivers. VCs are the financial intermediaries who invest the funds of their investors, which creates agency and information asymmetry problems between the VC managers and entrepreneurs on one hand, as well as between the VC investors, Limited Partners (LPs), and the VC managers, General Partners (GPs) on the other.

VCs has been the topic of a vast literature of which the following list gives only a small part: Sahlman (1990) , Admati and Pfleiderer (1994), Gompers (1995),Lerner (1995), Bergemann and Hege (1998), Hellmann (1998), Neher (1999), Kaplan and Stromberg (2000), Casamatta (2000), Cumming and MacIntosh (2001), Hellmann (2002), Casamatta and Haritchabalet (2003) and Malherbe (2003). However, the literature focuses mostly on the relations between the VC fund and the entrepreneur[1] and pays much less attention to the conflict of interests between LPs and GPs in the VC fund itself.[2] This is despite the fact that the highest claims in the project are held by LPs (typically 75-80% of VC share in the project), which makes them bear the most cost of any inefficiency. In this paper we consider just two examples of such inefficiencies stemming from the LP/GP agency problem: suboptimal termination and continuation decisions made by GPs in the final years of their VC funds' life. According to the NVCA, EVCA and IVA data, in the "post dot-com" period the average number of discontinued projects reached 30-60% of the overall number of exits, which is almost double the rate during the regular times. Industry sources suggest that *around 50% of the terminated projects are potentially "good" projects.* It seems that many good start-ups are abandoned at the same time when many VCs are looking for good

[1] Bergemann and Hege (1998), Repullo and Suarez (1998) and Casamatta (2000) are just few examples of studies of (dual) moral hazard in VC - entrepreneur relations. Kaplan and Stromberg (2000) document what instruments VCs use to alleviate this problem. Confirming theoretical predictions, convertible securities are the most frequently used ones in their sample.

[2] Notable exceptions are Lerner and Schoar (2004) and Aghion et al. (2004).

investment opportunities. Given the amount of funds committed by investors to this class of financial partnerships (over $180 billion at its peak in 2000), this inefficiency translates into the annual loss of billions of dollars, most of which is born by the LPs. There is no data on the inefficient continuation, but the problem may be of large proportions as well.

This paper presents a model that analyzes the agency and the information asymmetry problems that exist between GPs and LPs. The source of the problem in the model is the short horizon of the GP stemming from the finite life of the fund. To the best of our knowledge, no previous academic literature dealt with the negative effects of limiting the fund life to a finite period. A series of interviews with VC practitioners suggest that this type of inefficiency was not identified as a major concern in the industry practice either. We, therefore, present contractual arrangements to alleviate the problem in reality.

The essence of the model is in the fact that during the intermediate financing stage the GP obtains information about the quality of the project as well as about its expected time to exit. The first best solution demands that bad projects should be abandoned immediately, while good projects be continued (under the GP's monitoring) regardless of their exit time. However, the finite life span of the fund forces the GP to sell all the unfinished projects at the fair price. This implies that he prefers to present some bad projects as unfinished good ones, which forces him to invest in them in the meantime. In addition, he may not be sufficiently compensated by the contract to invest his monitoring resources into the "delay-prone" good projects, which destroys their chances for success.

We present several mechanisms to alleviate the problem. One possibility is to reduce the GP's stake in all unfinished projects, which would reduce his incentive to prolong bad projects, and, surprisingly, may indirectly increase his incentive to invest in the "delay-prone" good projects. Another mechanism is to award post VC non-vested cash rights to GP. Yet another one is to co-invest with a much younger fund, which does not face the same limitations, but have the same information as the lead VC.

We present several empirical predictions of this theory. We predict that: (i) funds that write off all the unfinished projects should exhibit higher average quality of projects, but

invest in more short term projects as well, (ii) syndicates of VC funds with different age would have lower termination rate of good projects than more homogeneous syndicates; (iii) proportion of successful exits decreases with the age of VC fund; (iv) the exogenous events of 2000, when all projects became less valuable, and more delay prone should have differing effects on funds with different contractual provisions.

The rest of the paper is organized as follows: Section II briefly describes the structure and organization of VC funds and identifies the nature of the problem. Section IV presents the formal model, the first best outcome, and the possible equilibria. Contractual solutions as well as several potential extensions are discussed in Section V. Section VII concludes.

II The VC Structure and Organization

In this section we describe a typical VC fund structure. We rely on Sahlman (1990), Kaplan and Stromberg (2000) as well as on various industry sources.

VC funds are organized in general as limited partnerships between two types of partners: several Limited Partners (LPs) and one General Partner (GP). LPs agree to make available their share in the fund whenever GP "calls for money" and in return receive a share in the fund profits. LPs are not actively involved in the fund operation and play vis-à-vis the VC a role similar to the minority shareholders in a public company.

The GP is managing the day-to-day ordinary activities of the fund: identifies appropriate projects, according to the charter of the fund, executes the due diligence and all the necessary tasks involved in investment in the selected projects, monitors the portfolio firms and assists the firms with managerial expertise and guidance.

GPs use a variety of methods that reduce the agency cost and improve the quality of information about the project. These methods are extensively covered by the academic literature of the last decade quoted in the introduction. In particular, it is a very common practice to execute the actual funds transfer to the firm in stages, contingent to certain conditions that must hold at the execution time. Some of these parameters are a direct result of firm's activities, others are environmental conditions related to the uncertainty char-

acteristics of risky projects, like market reaction, technology barriers and macroeconomic factors. The GP acquires new information on the project and adjusts its ex-ante estimated project value, length and cost accordingly. GP also take into account the opportunity costs of alternative investments in order to maximize the payoff of the entire portfolio, not only the specific project.

One other common practice is the syndicated investment in projects, which allows for superior diversification of the fund and collection of additional signaling on project's quality, as described in the model of Casamatta and Haritchabalet (2003).

The principal-agent relationship between LPs and GP receives less attention in both the academic and practitioners circles. The two main mechanisms that LPs can use in this sense are (i) the early fund liquidation by the LPs' robust majority and (ii) the limited life span of the fund.

The first mechanism allows LPs to stop investment and liquidate the fund before the contractual end time in extreme cases when GP severely underperforms and do not justify the contractual management fees. This mechanism is used in very rare cases since the asymmetric information of LPs and GP always allows the latter to hide the real quality of the portfolio projects till the normal end of fund life.

Limiting the fund life (usually to 5-10 years) allows LPs to limit the risk and discourage GP from retaining the profits within the fund by hiding infinitely the project maturity (see, e.g., Sahlman (1990)). More important, it creates incentives for GP to build reputation by performing well to be able to raise the next fund. LPs, in particular institutions, are usually well diversified investors with long investment horizon: the limited life span of the VC is not a necessity for them, but rather a reasonable control mechanism.

The distribution of payoffs from the fund's investments is in general as follows: the GP receives a management fee, generally as a percentage (1.5-2.5%) of the total fund size (total amount committed by the LPs). In addition, GP receives a percentage (generally 20% - usually called "carried interest") of the capital gains, which are the total exits proceeds received during the fund life less the amounts that LPs already transferred to the fund

as part of their commitment. LPs have the seniority of being paid back from the exits proceeds: only after they are paid in full the GP starts sharing the profits.

Residual assets, like stock, options and other contingent claims in projects that didn't reach yet a liquidation event (exit) are distributed between LPs according to their share in the fund.

It is easy to realize intuitively even in this phase that the different investment horizon of GP and LPs creates a conflict of interests in the way they estimate the value of projects: for GP, the value of projects that are not expected to reach the exit during the fund life is significantly lower that for the LPs, since it doesn't carry the value of its residual claim, that can still be exercised by LPs at a later stage.

The common strategy of VC funds is to execute investments intensively in the early stages of the fund, monitor and support portfolio firms in the mid-stage and accelerate the exit in the last stages. Analysis of VCs strategies with a complex three stage modeling effort is found in Malherbe (2003).

III Model

In this section we describe a model that we are using to analyze GP's decisions to continue/terminate projects at an intermediate stage. In real life, new investment opportunities emerge during the entire fund life, however, the problem of inefficient continuation/termination decision becomes more acute closer to the fund maturity, because it becomes less certain that the project will be finished before the fund's maturity. Therefore, without loss of generality and for the sake of simplicity, we consider a two-period model, in which the fund starts and long-term investment opportunities arise at the same time, $t = 0$.

Our analysis is conducted on an individual project level. We ignore interaction effects between different projects in the fund portfolio and questions of optimal portfolio size,[3] simply assuming that the number of projects in the VC portfolio is big enough to compensate

[3] Optimal portfolio size is studied in Kanniainen and Keuschnigg (2000), while for effects of interaction between portfolio projects see, for example, Leshchinskii (2002).

for the possible loss in one project — an argument similar to Diamond (1984). Therefore, we allow the project's **realized net** payoff to GP or LPs to be negative (of course, the **expected** net payoff should be greater or equal to zero).

Investors

We have a VC fund which has a time horizon from $t = 0$ to $t = 2$. That is, it is created at $t = 0$ and must be dissolved at $t = 2$. VC fund has two types of partners: one General Partner, GP, who manages the fund and limited partners, LPs, who are "passive" investors with cash claims only on the fund's profits. Often literature refers to GP as to VC and ignores LPs. LPs commit to provide the total amount of capital for investment.

At $t = 0$ VC is created and LPs commit (invest) money in the fund. We make the following assumption:

Assumption 1 *We assume that GP's compensation is linear and equal to* $\alpha \sum s_i - \alpha \sum I_i$*, where* s_i *is VC fund's claim in project* i *and* I_i *is the total amount invested by LPs in project* i*.*

As we have described in Section II, normally GP receives his compensation in two forms: as a pre-agreed management fee, which is in general a percentage (1.5-2.5%) of the fund size, and the "carried interest" - a significant part (20%) of the fund net capital gains — that is: the aggregate exits amount, less the aggregate amounts already invested in projects, which must be returned to LPs. Since in our model GP would invest all committed money at $t = 0$, we set the fund management fee to be equal to zero. Fraction α received by GP is exogenous to the model. We assume that it has been determined by the contract between GP and LPs to ensure "fair return" to investors.

Projects

GP can invest money into two types of projects (we assume zero interest rate for simplicity):

1. Long-term projects. They require investment I per period for two periods ($2I$ in total). They also require monitoring for two periods, which costs m per period and

which is not verifiable. By monitoring here we mean any kind of non-monetary effort, put by GP into the project, like screening, advising etc. Without monitoring the payoff to investors is always zero.[4] If monitoring takes place in both periods, the payoff is random, it is equal to V with probability p and zero with probability $(1-p)$. **The time of the payoff is random as well**. Long-term projects take 2 to 3 periods to finish. The prior probability that a project ends at $t = 2$ is q_0. If the project ends in two periods, GP can reveal this information, in which case the project's payoff becomes public knowledge. GP can also hide information about the project progress (claiming that the project didn't end yet) with the project payoff remaining unknown.[5] Intuitively, GP would tend to reveal the results of good projects, but to hide the results of bad projects, because he might get some positive profit from selling his stakes in projects, which have zero value. Long-term projects' payoff structure is depicted on Figure 1 in Appendix.

2. Short term projects, in which investment I gives investor payoff μ in one period. This project may also be interpreted as a "safe" restructuring of a risky long-term project by downsizing and refocusing it.

Assumption 2 *Proceeds from projects cannot be reinvested into new portfolio projects.*

Assumption 2 is a common practice of many VC funds. It means that at $t = 1$ GP cannot reinvest proceeds from a finished short term project into a new short-term project. He can invest, however, capital I, pledged by LPs. Assumption 2 allows us to ignore I, when comparing long-term and short-term projects.

[4] Although this assumption appears to impose a "non-credible" restriction, it is largelry accepted by both practitioners and academics, like in Gompers (1995).

[5] Whether GP can hide the project progress or its status and payoff becomes publicly known depends pretty much on the nature of the project itself. We can imagine that some outcomes are easier to hide than other. We assume that for early stage projects VC can easily conceal its progress. If one to assume that the value of finished projects is always observed at $t = 2$, the results become different (for example, there exists a separating equilibrium with fair pricing), but most of our results still hold. Analysis is available upon request.

At $t = 1$ the payoff to short-term projects (if there are any) is realized. For long-term projects, GP learns **for sure** the project's value. He also learns the true probability that the project will end at $t = 2$: $q \in \{q_L, q_H\}$. The LPs still only know the prior distribution of the project quality, $Prob(Good) = p$; as well as of the project length: $Prob(q_H) = \gamma$. Thus we have double information asymmetry on the part of the GP. Now he has to decide whether to continue the project (with or without monitoring it) or to abandon it and start a short-term project.

At $t = 2$ the VC fund must be dissolved. When the fund is liquidated, LPs first receive their investment back. The remaining part of the fund's claim is distributed between the partners, GP and LPs, according to the stakes they have and to projects' price π_i they agree on.[6] If the project has ended by $t = 2$ **and GP has revealed this information**, its true value becomes known and the project is sold (through an IPO or a trade sale) at its true value. If the project remains unfinished, as stated by the GP, then the GP must cash in his stakes, while LPs can still keep their stakes in the project. We assume that GP sells his stakes either to LPs or to outside investors at a fair price. We assume that there is no information asymmetry between LPs and outside investors.

The first best outcome

We derive the first-best outcome as a benchmark. Since the total investment is $2I$ under all circumstances, we ignore the investment part.

Once a signal about the project's quality is received, only good projects should continue, while bad projects should be replaced by new short-term projects. So, if a long-term project is started at $t = 0$, its expected payoff must exceed that of starting the short-term project from the beginning (we assume zero interest rate):

$$p\,(V - m) + (1 - p)\,\mu - m > 2\mu.$$

[6] In general, this is not the project liquidation — the project is simply sold or goes through an IPO, although its true value is not revealed yet. Of course, $\pi = 0$ is possible as well, for example, if its funding has been discontinued at $t = 1$.

This implies that the VC fund should invest in long-term risky projects iff:

$$V \geq (m + \mu) \frac{1 + p}{p} \tag{1}$$

Assumption 3 *We assume that inequality (1) holds.*

Assumption 3 for all projects ensures that VC funds have the right to exist.[7]

Expected payoff to GP

As we have mentioned before, when analyzing payoff to GP, we ignore interaction effects between different projects in the investment portfolio and question of the optimal portfolio size. Therefore, GP maximizes his utility by maximizing the expected payoff of each individual project. We allow for negative realizations of the project's random payoff to GP as long as the expected net payoff is positive — the number of projects in the VC portfolio is assumed to be big enough to make the probability of the net loss for the entire portfolio negligibly small.

Combination of the GP's short horizon and information asymmetry lead to inefficient decisions.

At $t = 1$ if GP continues a good project and provides monitoring m, then with probability q (GP knows its exact value $\{q_L, q_H\}$, while LPs know only its prior expectation $q_0 = \mathrm{E}\{q\}$) the project will end at $t = 2$ and its true value will be revealed, in which case VC fund will receive payoff V to distribute it between LPs and GP. With probability $(1 - q)$ the project will remain unfinished and GP will be obliged to sell his stake either to new investors or to LPs, who are equally uninformed. We also assume that before GP receives any proceeds from the project, LPs have to receive all the invested money back.

[7]Notice that at $t = 0$ the value of the real option to abandon the project and to replace it by a short-term project at $t = 1$ is

$$\begin{aligned} &[p(V - m) + (1 - p)\mu - m] - [pV - 2m] \\ &= (1 - p)(\mu + m) \end{aligned}$$

which is the sum of the values of the abandonment option, $(1 - p)m$ and the replacement option, $(1 - p)\mu$.

Therefore, if at $t = 1$ GP observes that the project payoff to VC will be V (the project is good) and most likely will finish in time ($q = q_H$), then given that he supplies effort m and given Assumption 1, GP expects to receive at time $t = 2$ payoff

$$\alpha\left[q_H V + (1 - q_H)\,\pi\right] - m. \tag{2}$$

First-period monitoring is a sunk cost by this time and does not count; neither do the investments, since they are the same in all scenarios.[8] If at $t = 1$ GP observes that the project is good, but is "delay-prone" ($q = q_L$), then if he supplies effort m, he expects to receive at time $t = 2$ payoff

$$\alpha\left[q_L V + (1 - q_L)\,\pi\right] - m. \tag{3}$$

If at $t = 1$ GP observes that the project is bad, yet does not terminate the project, then his expected time $t = 2$ payoff is $\alpha\pi$. If at $t = 1$ the long-term project was dropped in favor of the short-term project, then the payoff is $\alpha\mu$.

Determination of π

We assume that π is the expected value of the project, conditional on the fact that it is unfinished.[9] This implicitly assumes that outside investors are risk neutral, and the market

[8] Again, we are not imposing $\pi - 2I - m > 0$, thus allowing some realizations of particular projects to be negative. One might think that we assume unlimited liability here, but we simply assume that the pool of projects is high enough to compensate for the possible loss in one project — an argument similar to Diamond (1984)

[9] It is possible to imagine a situation, in which $\pi \neq \mathrm{E}\{value|\text{no information revealed}\}$. For example, at $t = 0$ GP can sell LPs a forward contract with a predetermined price π on all unfinished at $t = 2$ projects. This pricing can possibly improve efficiency of GP's decision concerning project's termination/continuation by creating a commitment mechanism to terminate bad projects. We will show rationale for that in Section IV.

In real life, in some funds GP always terminate all unfinished project at VC fund maturity, which is the same as having $\pi = 0$. GPs of these funds explain that they prefer to do that, rather than let some other VC fund to take the credit of bringing a new star company to the market.

is competitive. Formally,

$$\pi = \mathrm{E}\left\{value \mid \text{unfinished project}\right\} = V \cdot \Pr\left\{V \mid \text{unfinished project}\right\}$$
$$= V \cdot \frac{\Pr\left\{\text{unfinished project}|V\right\}\Pr\left\{V\right\}}{\Pr\left\{\text{unfinished project}|V\right\}\Pr\left\{V\right\} + \Pr\left\{\text{unfinished project}|0\right\}\Pr\left\{0\right\}}. \quad (4)$$

Notice that if $\Pr\{0\} = 0$,then we know for sure that all bad projects are terminated at $t = 1$, in which case $\pi = V$.

IV Results

First, we consider whether the first best outcome is achievable. This would require that all bad projects are terminated at $t = 1$, and GPs invest in short term projects. In our model this would necessitate that $\mu > \pi$, where π is the price that GP gets for unfinished project. Then whenever the GP considers continuing a bad project, he would rather invest in the sure thing, and get a higher reward. This implies that whenever we observe an unfinished project, we know that it is a good one, which according to equation (4) implies that $\pi = V$. Given our earlier assumption about this equilibrium it must be that $\mu > V$, which contradicts Assumption 3. This is the first result of the paper. Formally, we have:

Proposition 1 *For competitive pricing of unfinished projects at $t = 2$ ($\pi = \mathrm{E}\{value|no\ info\}$) no equilibrium exists in which bad projects will be terminated at $t = 1$ for sure.*
Proof. *Suppose that such an equilibrium exists. Since all bad projects will be terminated and $\Pr(0) = 0$, by equation (4) we should have $\pi = V$. In order to terminate the bad project, GP should have payoff from its continuation less than payoff from starting a safe project, i.e. $\pi \leq \mu$, which implies that $V \leq \mu$. This in turn contradicts Assumption 3* ■

For competitive pricing of unfinished projects at $t = 2$ the only possible pure strategy equilibria are pooling equilibria. If μ and m are small, then all projects will continue at $t = 1$. If μ is high ($\mu > V$), only "safe" projects will get funding.

This is a very important result, because it shows that with competitive pricing we always have inefficient outcomes. Efficiency can be improved either by some randomization of GP's actions or by relying on pricing mechanisms other than competitive pricing.

Next, let us check whether good projects are ever chosen to be continued at $t = 1$. If they are not, then any unfinished project is worthless, i.e., $\pi = 0$, which is a contradiction. This means that at least when $q = q_H$ GP must decide to continue monitoring the good project. This leaves us with two options: either the good projects are always monitored (q_L is sufficiently high), or when $q = q_L$ GP decides to stop monitoring and sell the project as an unfinished one. Let us consider the first case.

Equilibrium with monitoring of all good projects

What is the *a priori* probability of observing an unfinished project under these assumptions? There are three possible scenarios:

Scenario	Probability
Bad project	$1 - p$
Good project with q_L	$p(1-\gamma)(1-q_L)$,
Good project with q_H	$p\gamma(1-q_H)$
Probability of Observing an Unfinished Project	$1 - pq_0$

where

$$q_0 \equiv q_L + \gamma(q_H - q_L)$$

Using expression (4) for competitive pricing under equilibrium beliefs that all projects are continued, we find that the expected value of the project, conditional on the fact that it is not finished, is therefore

$$\pi_1 = V\frac{p\,(1-q_0)}{p\,(1-q_0)+(1-p)} = V\frac{p\,(1-q_0)}{1-pq_0}. \tag{5}$$

We must now impose two conditions: first, that the beliefs above are consistent with the actual strategy, and second is that GP prefers to invest in the long-term project.

GP must prefer to monitor a project even when he observes $q = q_L$. This condition is:

$$\alpha q_L V + \alpha(1-q_L)\pi_1 - m \geq \alpha\pi_1.$$

Rearranging, we obtain the first condition:

$$m \leq q_L \alpha V \frac{1-p}{1-pq_0}$$

The expected value of the GP's stake in the long-term project at period $t = 0$ must be greater than his stake in two short-term projects, given that he monitors all good projects:

$$\alpha p \left[q_0 V + (1-q_0)\pi_1\right] + \alpha(1-p)\pi_1 - m(1+p) > 2\alpha\mu.$$

Rearranging, and substituting π_1 we get:

$$m \leq \frac{\alpha\,(pV - 2\mu)}{(1+p)}.$$

Thus this equilibrium exists whenever:

$$m \leq \min\left\{q_L \alpha V \frac{1-p}{1-pq_0}, \frac{\alpha\,(pV-2\mu)}{(1+p)}\right\}.$$

This implies that the probability of delay must be small enough for all projects for the efficient continuation to be maintained. Heterogeneity among projects with respect to their chances of delay will invalidate this equilibrium. Events such as occurred in 2000 significantly reduced the levels of q for all projects, which suggests that the problem of inefficient continuation decision became more acute in recent years, as conjectured in the industry.

Equilibrium with no monitoring of "delay-prone" projects

In this equilibrium good projects are continued only when the probability of getting them done on time is sufficiently high, and are the monitoring is stopped otherwise. If monitoring cost m is relatively high, the benefits of monitoring will not justify its cost to GP.

What is the *a priori* probability of observing an unfinished project under these assumptions? Since monitoring will be continued only for good projects with probability of finishing at $t = 2$ q_H, the probability of observing an unfinished project at $t = 2$ is $1 - p\gamma q_H$.

The expected value of the project, conditional on the fact that it is not finished, is above zero only when the project is good and $q = q_H$:[10]

$$\pi_2 = V\left(\frac{p\gamma - p\gamma q_H}{1 - p\gamma q_H}\right). \tag{6}$$

We must again impose the condition that the beliefs above are consistent with the actual strategy, and that the project is undertaken at the beginning.

GP must prefer to monitor a project when he observes $q = q_H$, and not to monitor when he observes $q = q_L$. These conditions are:

$$\alpha q_H V + \alpha(1 - q_H)\pi_2 - m \geq \alpha\pi_2,$$

and

$$\alpha q_L V + \alpha(1 - q_L)\pi_2 - m < \alpha\pi_2,$$

Substituting the value of π_2 we get:

$$\alpha q_H V \frac{1 - p\gamma}{1 - p\gamma q_H} \geq m > \alpha q_L V \frac{1 - p\gamma}{1 - p\gamma q_H}.$$

The expected value of the GP's stake in the long-term project at period $t = 0$ must be greater than his stake in two short-term projects, given that he monitors only good projects with $q = q_H$:

$$\alpha\left[p\gamma q_H V + (1 - p\gamma q_H)\pi_2\right] - m(1 + p\gamma) \geq 2\alpha\mu.$$

Substituting π_2 and rearranging, we obtain:$m \leq \frac{\alpha p\gamma V - 2\alpha\mu}{(1+p\gamma)}$.

Thus the conditions for the existence of the equilibrium with inefficient termination of

[10] Notice that π_2 is decreasing in q_H:

$$\frac{\partial\left(\frac{p\gamma - p\gamma q_H}{1 - p\gamma q_H}\right)}{\partial q_H} = -\frac{p^2\gamma^2 q_H(1 - p\gamma)}{(1 - p\gamma q_H)^2}.$$

"delay-prone" good projects is

$$\min\left\{\alpha q_H V\frac{1-p\gamma}{1-p\gamma q_H}, \frac{\alpha p\gamma V-2\alpha\mu}{(1+p\gamma)}\right\}\geq m>\alpha q_L V\frac{1-p\gamma}{1-p\gamma q_H}.$$

We summarize this section with the following proposition:

Proposition 2 *In the game described above there exist two types of equilibria in pure strategies:*

1. *For m satisfying*
$$m\leq\min\left\{q_L\alpha V\frac{1-p}{1-pq_0}, \frac{\alpha\left(pV-2\mu\right)}{(1+p)}\right\},$$
there exists an equilibrium in which all projects are continued, and all the good projects are monitored. The expected total payoff of the VC in this case is Vp.

2. *For m satisfying*
$$\min\left\{\alpha q_H V\frac{1-p\gamma}{1-p\gamma q_H}, \frac{\alpha p\gamma V-2\alpha\mu}{(1+p\gamma)}\right\}\geq m>\alpha q_L V\frac{1-p\gamma}{1-p\gamma q_H},$$
there exists an equilibrium in which all projects are continued. Good projects that are "delay prone" are not monitored, while the others are. The expected total payoff of the VC in this case is $Vp\gamma$.

Notice that an increase in μ and in p, as well as a decline in q_L, α, and V reduce the region in which all good projects are monitored. The crash of the market in 2000 clearly significantly reduced V and q_L, which suggests that the inefficient region had increased quite dramatically. There may have been a small offsetting effect if p declined as well. This event is a good candidate for an empirical study in light of this model.

V Extensions

First we would like to analyze a few special cases to identify the source of the results presented above. In particular, suppose that all the projects are good, and this fact is a

common knowledge. In terms of the model this is tantamount to $p = 1$. This rules out the inefficient continuation of bad projects, since there are none. The question is

whether some good projects are terminated. Modifying Proposition 2 we immediately see that the equilibrium in which all good projects are continued is no longer viable, thus any pure strategies equilibrium involves inefficient termination of "delay prone" projects. The intuition is straightforward: if all good projects are continued, GP gets the same payoff for the "delay prone" projects whether he monitors or not, which causes him not to monitor them. A pure strategy equilibrium with partial monitoring exists iff:

$$\min\left\{\alpha q_H V\frac{1-\gamma}{1-\gamma q_H}, \frac{\alpha\gamma V-2\alpha\mu}{(1+\gamma)}\right\} \geq m > \alpha q_L V\frac{1-\gamma}{1-\gamma q_H},$$

For values of m higher than the LHS of the above inequality no VC funds exist, while for the lower m we obtain a mixed strategy equilibrium (see below).

1 Mixed strategy equilibrium

There might exist mixed strategy equilibria, in which bad projects sometimes (randomly) continue, while all the good projects are continued. Let us denote by θ the probability that a bad project is continued. Then it must be that $\pi = \mu$. Under these conditions the probability of observing an unfinished project is:

Scenario	Probability
Bad project	$\theta(1-p)$
Good project with q_L	$p(1-\gamma)(1-q_L)$
Good project with q_H	$p\gamma(1-q_H)$
Probability of Observing an Unfinished Project	$p(1-q_0)+\theta(1-p)$

Using expression (4) for competitive pricing under equilibrium beliefs that all good projects are continued, we find that the expected value of the project, conditional on the fact that it is not finished, is therefore

$$\pi_3 = V\frac{p(1-\gamma)(1-q_L)+p\gamma(1-q_H)}{p(1-q_0)+\theta(1-p)} = V\frac{p\,(1-q_0)}{p(1-q_0)+\theta(1-p)} = \mu. \tag{7}$$

This implies that the equilibrium value of θ is:

$$\theta^* = \frac{p\,(1-q_0)\,(V-\mu)}{(1-p)}. \tag{8}$$

We must again impose two conditions: first, that the beliefs above are consistent with the actual strategy, and second is that GP prefers to invest in the long-term project.

GP must prefer to monitor a project even when he observes $q = q_L$. This condition is:

$$\alpha q_L V + \alpha(1-q_L)\mu - m > \alpha\mu.$$

Rearranging, we obtain the first condition:

$$m \leq \alpha q_L(V-\mu). \tag{9}$$

The expected value of the GP's stake in the long-term project at period $t = 0$ must be greater than his stake in two short-term projects, given that he monitors all good projects:

$$\alpha p\,[q_0 V + (1-q_0)\mu] + \alpha(1-p)\mu - m(1+p) > 2\alpha\mu.$$

Rearranging, and substituting π_1 we get:

$$m \leq \frac{\alpha\,[pq_0 V - (1+pq_0)\mu]}{(1+p)}.$$

Thus this equilibrium exists whenever:

$$m \leq \min\left\{\alpha q_L(V-\mu), \frac{\alpha\,[pq_0 V - (1+pq_0)\mu]}{(1+p)}\right\}. \tag{10}$$

Similarly we can derive a mixed strategy equilibrium in which "delay prone" projects are terminated. We show that with competitive pricing of unfinished projects there always exists an inefficiency in the form of continuation of bad projects — either they are continued with certainty in pure strategy equilibria or they are continued with a positive probability in mixed equilibria.

VI Contract Design

In this section we analyze several contractual provisions that may alleviate the problem, and suggest that some of them are used in the industry in somewhat different forms.

1 GP gets a lower stake for unfinished projects

Suppose the GP gets a lower stake in all unfinished projects. Let us denote this lower stake by $k\alpha$ ($k < 1$). We show below that if k is low enough, then we can achieve the first best in some cases. The solution is reminiscent of optimal debt contracts that are contingent on the state of nature. Here as well, if the project is unfinished, the GP contract is different than that for a finished project, which produces incentives for him to avoid the former state of nature.

To achieve the first best would require that GP terminates bad projects, which implies that $\mu > k\pi$; despite the fact that $\pi = V$.

GP is not tempted to continue bad projects since he only gets $k\alpha$ of the unfinished project, while α of the finished one. This requires (along with Assumption 3) that

$$k < \frac{\mu}{V}. \tag{11}$$

Obviously, inequality (11) also implies that GP will never stop monitoring good projects if he decides to continue them. The question remains whether GP would like to continue the "delay prone" projects or to replace them by the safe ones. In fact he would continue iff:

$$m \leq \alpha \left\{ V \left[q_L + k(1 - q_L) \right] - \mu \right\}. \tag{12}$$

This would yield the first best outcome. For higher values of m "delay prone" good projects will be replaced by short-term projects at time 1.

GP must also be willing to invest in the long-term project at $t = 0$. If GP expects to continue all good projects, then the following condition be satisfied:

$$\alpha p q_0 V + k\alpha p(1 - q_0)V + \alpha(1 - p)\mu - m(1 + p) > 2\alpha\mu.$$

This gives the lower bound on k :

$$k > \frac{(1+p)(\alpha\mu+m)}{\alpha p(1-q_0)V} - \frac{q_0}{(1-q_0)},$$

were m satisfies (12).

If (11) holds, but (12) does not, GP is expected to continues only the "in-time" projects while abandoning the "delay prone" projects. At $t=0$ a similar condition is:

$$\alpha p\gamma q_H V + k\alpha p\gamma(1-q_H)V + \alpha(1-p\gamma)\mu - m(1+\gamma p) > 2\alpha\mu,$$

$$k > \frac{(1+\gamma p)(\alpha\mu+m)}{\alpha p\gamma(1-q_H)V} - \frac{q_H}{(1-q_H)}, \tag{13}$$

where $m > \alpha\left\{V\left[q_L + k(1-q_L)\right] - \mu\right\}$

The ex ante expected total payoff of the VC under this contract is:

$$\begin{array}{cc} pV + (1-p)\mu & \text{if continue all good projects} \\ p\gamma V + (1-\alpha)(1-p\gamma)\mu & \text{if continue "in-time" projects} \end{array} \tag{14}$$

The added value comes from two sources: first, termination of bad projects contributes the value of short term projects times the probability they are undertaken when the long-term project is bad. Second, the equilibrium yields efficient continuation of good projects under a wider range of parameters.

In reality some GPs have a policy of terminating all the unfinished projects at $t=2$, rather than selling them, i.e. $\pi=0$. This seemingly irrational policy is a somewhat drastic form of the abovementioned policy (k in this case is equal to zero). It may improve efficiency because it leads to early termination of all bad projects. Clearly, the termination of all bad projects is a dominant strategy. But the side effect of setting k to zero is that the first best is achievable only if $m \leq \alpha\left\{Vq_L - \mu\right\}$ and

$$\frac{(1+p)(\alpha\mu+m)}{\alpha pV} < q_0,$$

which describes a narrower range of parameters' values than the contractual provision suggested above.

2 GP keeps cash flow claims for unfinished projects

Another possibility to alleviate the problem is to extend the interests of the GP beyond the end of the VC. As pointed above, LPs would not like to extend the control rights of the GP beyond the pre-agreed time to control for opportunistic behavior of the GP, but they would not be averse to extending the cash flow rights. Suppose that these cash flow rights allow the GP to get $z\alpha$ of the project when it comes to fruition, and he is not allowed to sell these rights before that. LPs will set z to the lowest level that ensures efficiency.

This provision immediately ensures that GP always terminates bad projects, since his payoff from them is zero. This implies that all unfinished projects must be good, which again implies that $\pi = V$.

GP would monitor "delay prone" projects if and only iff the payoff from the delayed project exceeds that of the short term one:

$$\alpha q_L V + z\alpha(1 - q_L)V - m > \alpha\mu.$$

Rearranging, we get the minimal value of z that ensures that all good projects are monitored:

$$z > \frac{\alpha\mu + m - \alpha q_L V}{\alpha(1 - q_L)V}. \tag{15}$$

GP must also be willing to invest in the long-term project at $t = 0$. When all good projects are monitored, then the following condition be satisfied:

$$\alpha p q_0 V + z\alpha p(1 - q_0)V + \alpha(1 - p)\mu - m(1 + p) > 2\alpha\mu.$$

This gives another lower bound on z:

$$z > \frac{(1 + p)(\alpha\mu + m)}{\alpha p(1 - q_0)V} - \frac{q_0}{(1 - q_0)}. \tag{16}$$

Thus as long as

$$z \geq max\left\{\frac{\alpha\mu + m - \alpha q_L V}{\alpha(1 - q_L)V}, \frac{(1 + p)(\alpha\mu + m)}{\alpha p(1 - q_0)V} - \frac{q_0}{(1 - q_0)}\right\},$$

the equilibrium attains the first best, and yields similar increase in the overall payoff for the fund as the contractual provision discussed before.

3 VC syndication

As a modification of the previous suggestion, a VC with a short time horizon may invest together with another VC at $t = 0$, which would eliminate his information asymmetry later on. In such a case the other VC can purchase only the good unfinished projects, which would eliminate the continuation of the bad ones. Here we assume that GPs of both VC funds are involved in monitoring activity and there is no information asymmetry between them. Efficiency is achieved at the cost of excessive monitoring (by both GPs).

VII Conclusion

The problem we study stems from the GP's myopia induced by the finite life span of the VC, and by his superior information relative to other agents. Our model shows that under these conditions the first best is not attainable with linear contracts. In fact, inefficient continuation of bad projects is almost sure, while in many cases inefficient termination of good project is also present in equilibrium.

This paper is the first (as far as we know) attempt to analyze the negative effects of limiting the VC life, which is a controlling device to solve agency and informational asymmetry problems between GP and LPs. We developed a simple model that reveals the suboptimal nature of continuation/write-offs decisions few years before the fund maturity. We show that both selling unfinished projects at competitive "fair" price and termination of all unfinished projects at the fund maturity create suboptimal outcomes, although of different nature. A VC fund, in which GP sells his stakes at a competitive price, tends to continue all poor quality projects, thus decreasing the overall quality of portfolio projects. A VC fund, which has a practice of terminating all unfinished projects at its maturity, should have much higher quality of its portfolio, but this result comes at the cost of writing-off some good projects long before the fund maturity.

We propose several contractual remedies: lower stakes on the unfinished projects for the GP, retention of cash rights by the GP in the unfinished projects, and costly quality verification. In addition a simple syndication between the short-horizon fund and a long-horizon one would also alleviate the problem.

Our results have the following empirical implications: (i) funds that write off all the unfinished projects should exhibit higher average quality of projects, but invest in more short term projects as well, (ii) lower termination of good projects in older funds that invest in syndication with younger funds; (iii) proportion of successful exits decreases with the age of VC fund; (iv) the exogenous events of 2000, when all projects became less valuable, and more delay prone should have differing effects on funds with different contractual provisions.

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A Appendix

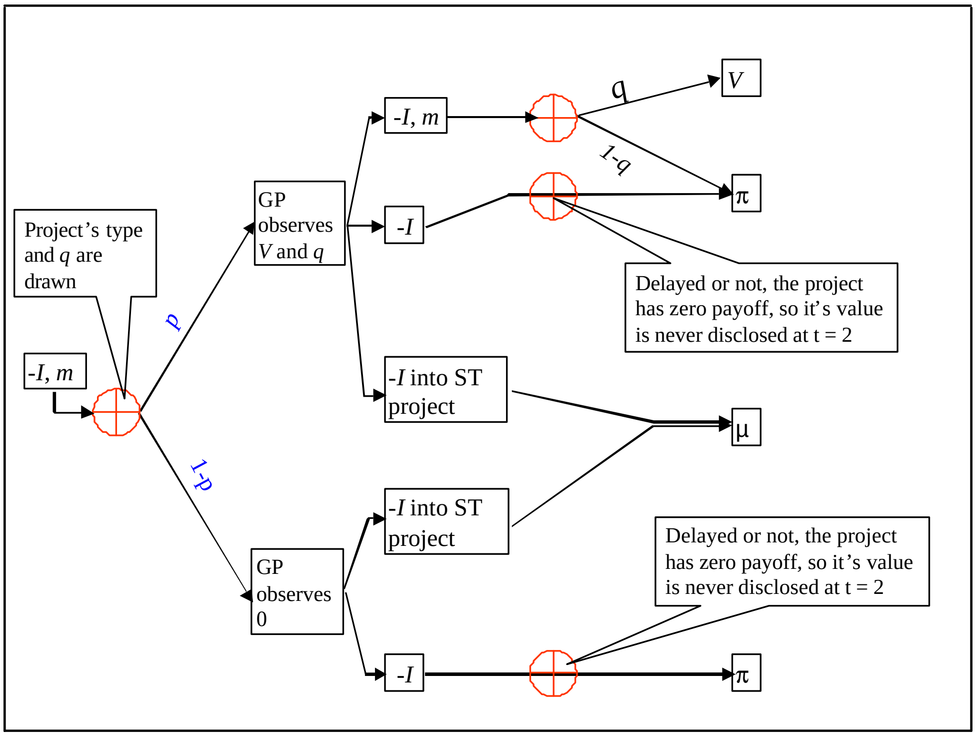

Figure 1: Long-term project payo¤ to VC fund. One period before the fund maturity GP observes the project quality(payo¤ to the fund is V for a good project and 0 for a bad one) and probability q of its ending by the fund maturity. GP must decide, whether to continue investment I and monitoring m of the project or to replace it by a short term project with investment I and payo¤ to the fund μ. π is the value of the project of unknown quality, i.e., it does not …nish by the fund maturity or its value is not disclosed.