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START-UP FUNDING INEFFICIENCIES DUE TO VC S LIMITED HORIZON

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Abstract

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 monitoring effort for each project. We assume that midway into the project, the GP privately observes its quality and the estimated time to exit and decides whether to continue investing and monitoring. The limited time horizon of the fund forces the GP to dispose of any unfinished projects when the fund is dissolved. This, combined with the informational advantage of the GP, leads to inefficient decisions during the intermediate investment stages: frequent continuations of bad projects, as well as occasional write-offs of good, but delay-prone, projects.

This paper presents a simple model that identifies the source and extent of this inefficiency. We show that when unfinished projects are fairly priced, bad projects are always continued. At the same time, under a wide range of parameter values good projects with a somewhat longer expected completion time may be discontinued, since the GP optimally decides not to invest monitoring effort in them. We show that the magnitude of the efficiency loss can be in excess of 25% of the first-best surplus, and 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, since their price increases. 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. We also show that allocating non-vested cash (but not decision) rights in the unfinished projects to the GP has similar beneficial effects.

Key words: Venture Capital, Agency Problem, Start-ups, Project Selection

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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 leading economic drivers. VCs are the financial intermediaries who invest the funds of their investors, on their behalf. This creates double agency and information asymmetry problems: between the VC managers and entrepreneurs on one hand, and between the VC investors (Limited Partners or LPs) and the VC managers (General Partners or GPs) on the other.

Conflict of interests in the VCs has been the topic of a vast literature in Finance; the following list being only a small sample: Sahlman (1990) , Admati and Pfleiderer (1994), Gompers (1995), Lerner (1995), Bergemann and Hege (1998), Hellmann (1998), Neher (1999), Kaplan and Stromberg (2003), 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 the GP.[2] In this paper we consider two types of inefficiency stemming from the LP/GP agency problem: good projects' suboptimal termination and bad projects' continuation as a result of decisions made by GPs in the final years of their VC fund's life. According to industry reports, the average number of discontinued projects in the "post dot-com" period reached 30-60% of the overall number of exits, which is almost double the rate compared to earlier periods. 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 as many VCs are looking for good 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 the cost is borne by the LPs, who typically hold 75-80% of the VC share in the project. There is no data on the inefficient continuation, but the problem may be of large proportions as well.

According to Gompers and Lerner (1996), starting from early 80s majority of VC organizations became organized as a limited partnership (VC fund), which by 1992 became the dominant form of VC organization accounting for more than 80 percent of total VC pool. In this paper we focus on the conflict between the GP and the LPs that stems from the finite life of the fund, typically of 10 years with a possible extension from 1 to 3 years, which is a part of the contract aimed at reducing the ability of the GP to hold up the LPs once the latter have committed to invest; see Sahlman (1990) and Gompers and Lerner (1996). Therefore, at the time of making investment decisions, the GP is uncertain about future renegotiation. Such mechanisms are used in solving ex-post renegotiations, and soft-budget constraints problems.[3] In Corporate Finance literature a similar rationale is behind the requirement for limited debt maturity (see Benmelech (2004) for review): the larger the ex-post hold-up potential, the shorter the debt maturity. While this contractual provision is required of VCs for the same reason, to the best of our knowledge no previous academic literature deals with its costs, which, as we show, are not trivial. Our interviews with VC practitioners suggest that these costs were not a major concern in the industry, and only started to surface after the crash of 2000.

The model is driven by 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 requires that bad projects are abandoned immediately, while good projects are 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. We show that if the GP sells unfinished projects at their fair price, then the first-best outcome is never attainable, because the GP prefers to continue bad projects and sell them 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 delay-prone good projects, which destroys their chances for success.

We illustrate the extent of this problem, and show that for reasonable parameter values the efficiency loss ranges between 10-25% of the total surplus that can be generated by the VC in the first-best scenario. We also suggest that an exogenous shock that increases the probability of a longer exit time should significantly increase these inefficiencies. The evidence in the post-2000 period is consistent with this prediction. Indeed, it brought the problem to the attention of the practitioners.

We present several mechanisms to alleviate the problem. As in soft-budget constraints problems, the GP needs a credible commitment mechanism to terminate bad projects. One possibility is to reduce the GP's stake in all unfinished projects, which would reduce his incentive to prolong bad projects, and indirectly increase his incentive to invest in the delay-prone good projects. Another mechanism is to award cash rights in the unfinished projects to the GP, so that he would be able to harvest the fruits of his efforts. 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 implications of this theory: the misalignment of the GP's and the LPs' incentives (and consequently the loss of efficiency) increased in the "post-bubble" period, due to structural changes in exogenous parameters influencing the GP's behavior. Moreover, VC funds that write off all the unfinished projects, or allow the GP's to maintain cash flow rights in unfinished projects, should exhibit a higher average quality of projects, and better profitability. Syndicates of VC funds of different age have a lower termination rate of good projects than more homogeneous syndicates. However, the proportion of successful exits decrease with the age of the VC fund. 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 and on projects belonging to different industry/technology segments.

The rest of the paper is organized as follows: Section 1 briefly describes the structure and organization of VC funds and identifies the nature of the problem. Section 2 presents the formal model and the first-best outcome. Section 3 presents our results — the possible equilibria, while endogenous α is being found in Section 4 and possible contractual solutions to the problem are given in Section 5. Section 6 discusses empirical implications and 7 concludes.

1 VC Structure and Organization

In this section we describe a typical VC fund structure. We rely on Sahlman (1990), Gompers and Lerner (1996), Gompers and Lerner (1999), Kaplan and Stromberg (2002) and Kaplan and Stromberg (2003), as well as on various industry sources.

As we have mentioned, nowadays a vast majority of VC funds is organized as limited partnerships between two types of partners: several Limited Partners (LPs) and one General Partner (GP). LPs commit to a pre-specified amount of investment in the fund, whenever the GP "calls for money," and in return receive a share in the fund's profits. LPs are not actively involved in the fund operation and play a role similar to that of minority shareholders in a public company with probably even more limited means to control GP's decisions. As Gompers and Lerner (1996) state, "a single partnership agreement governs the relationship between the limited and general partners over the fund's life of a decade or more. Unlike other agreements these contracts are rarely renegotiated."

The GP manages the ordinary day-to-day activities of the fund: he identifies projects according to the charter of the fund, executes "due diligence" and all necessary tasks associated with investment in the selected projects, monitors the portfolio firms and assists them with managerial expertise and guidance.

The GP uses a variety of methods to reduce agency cost and improve the quality of information about the project. These methods are extensively studied in the literature of the last decade. In particular, a common practice is to execute the financing in stages, contingent to certain performance criteria, some directly related to the results of the firm's activities, while others are more environmental, such as market reaction, technology barriers, and macroeconomic factors. In the process, the GP acquires new information on the project and adjusts its estimated value, length, and cost accordingly. The GP also takes into account the opportunity costs of alternative investments in order to maximize the payoff of the entire portfolio, not only the specific project. Another common practice is syndicated investment in projects, which allows for higher diversification of the fund's portfolio, and yields additional opinions about the project's quality, as in Casamatta and Haritchabalet (2003). 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 VC strategies with three-stage modeling is found in Malherbe (2003).

The principal-agent relationship between the LPs and the GP has received little attention in both academic and practitioner circles. Notable exceptions are Sahlman (1990), Gompers and Lerner (1996), Gompers and Lerner (1999) and Lerner and Schoar (2004). The main mechanisms that LPs use to control the GP are (i) the limited life span of the fund, which is typically fixed at 10 years with possible extension of another 1 to 3 years (see, e.g., Gompers and Lerner (1999)), (ii) covenants in partnership agreements, and, in extreme cases, (iii) an early fund liquidation by the LPs' supermajority. The latter mechanism allows LPs to stop investment and liquidate the fund before the contractual time in extreme cases when the GP severely underperforms and does not justify the contractual management fees. This mechanism is used very rarely since the asymmetric information of the LPs and the GP always allows the latter to hide the real quality of the portfolio projects till the normal end of the fund's life.

Limiting the fund's life span, usually to 10 years, allows LPs to limit the risk and to discourage the GP from retaining the profits within the fund by infinitely hiding the project's maturity (see

Sahlman (1990)). More importantly, it creates incentives for the GP to build reputation by performing well in order to be able to raise money for the next fund. Gompers and Lerner (1999) found that compensation is higher for older and larger venture capital organizations, while "reputational concerns lead young venture capitalists with little incentive compensation to work hard and perform well." However, the signaling feature of reputation is relevant for the VC type, not the individual portfolio project type. Thus, proven that the overall performance of the fund matches expectations, individual project behavior has no impact on reputation considerations.

LPs, mostly 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, usually 1.5-2.5% of the total fund size committed by the LPs. In addition, the GP receives about 20% – usually called "carried interest" – of the capital gains, which are the total proceeds received during the fund's life less the amounts that the LPs already transferred to the fund as part of their commitment. LPs have the seniority of being paid back from the proceeds: only after they are paid in full does the GP start sharing the profits. It is important to mention that deviations from 20% of carried interest are quite rare and small. Gompers and Lerner (1996) explain that deviations from the standard 80%/20% divisions of profits are likely to attract widespread attention, while covenants represent a less visible way to make price adjustments. While Gompers and Lerner (1999) document about a one percent greater share commanded by oldest and largest venture groups, the GP's share always remains constant for all portfolio projects of the same fund. To the best of our knowledge, carried interest has never been contingent on the portfolio company performance.

Holdings in projects that did not reach the exit by the time of the fund's liquidation are distributed among LPs according to their share in the fund. The GP is not allowed to keep his shares, and has to sell them to the LPs or to outside investors. Protective covenants often prohibit or severely restrict selling these shares to later funds of the same VC firm (Gompers and Lerner (1996)). These instruments are necessary in order to minimize moral hazard problems within the context of heavily asymmetric information between LPs and GPs.

In practice, there are additional tools to mitigate the information asymmetry problem, such as the secondary trade of rights in unfinished projects (there are funds specialized in such trade). However, the VC secondary trade represents a minor proportion of the VC related transactions.

It is obvious at this stage that the different investment horizon of the GP and the LPs has the potential to create a conflict of interests, and distort the valuation of the same projects: for the GP, the value of projects that are not expected to reach the exit during the fund's life is significantly lower than for the LPs, since it does not carry the value of its residual claim, which can still be exercised by the LPs at a later stage.

2 Model

In this section we present a model to analyze the GP's decisions to continue/terminate projects at the intermediate stage. In real life, new investment opportunities emerge during the fund's entire life. However, the problem of an inefficient continuation/termination decision becomes more acute closer to the fund's maturity, because the probability of ending up with an unfinished project increases in 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 at an individual project level. We ignore interaction effects between different projects in the fund portfolio and questions of optimal portfolio size,[4] simply assuming that the number of projects in the VC portfolio is large enough to compensate for the possible loss in one project — an argument similar to Diamond (1984). Therefore, we allow in any single project the **realized net** payoff to the GP or the LPs to be negative (of course, the **expected** net payoff is greater than or equal to zero).

2.1 Investors

A VC fund exists for two periods: it is created at $t = 0$ and must be dissolved at $t = 2$. Although VC funds usually have more than two rounds of financing, the phenomenon we are studying becomes important towards the end of the fund life, which allows us to use a two-stage financing.

The fund has two types of partners: one General Partner, the GP, who manages the fund and limited partners, LPs, who are "passive" investors with cash claims on the fund's profits. Often literature refers to the VC as if it were the GP, and practically ignores the LPs. The LPs commit to provide the entire capital for investment.

At $t = 0$ VC is created and the LPs set the terms of the contract and invest in the fund. We make the following assumption:

Assumption 1 *We assume that the GP's compensation is linear in the fund's profit.*

As we have described in Section 1, the GP normally 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", α, - a significant part (e.g., 20%) of the fund's capital gains. Since in our model the LPs do not learn the quality of the project at $t = 1$, we assume that they always provide the capital "on call" and we set the fund management fee to be equal to zero without loss of generality. At this stage we treat α as exogenous to the model, but later we endogenize it as part of the contract between the GP and the LPs. As we have mentioned in Section 1, although α can vary across different funds as shown on Figure 1 in Gompers and Lerner (1999), it remains the same for all portfolio companies of a given VC fund. As we will show, the linear structure of the GP's compensation is the driving force of an inefficient continuation decision.

2.2 Projects

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

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 is not verifiable. By monitoring we mean any kind of unobservable effort the GP must put into the project, like screening, advising, etc. Without monitoring, the payoff to investors is always zero.[5] 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 crucial assumption is that the timing of the payoff is random as well**. Long-term projects can take either two or three periods to finish. The prior probability that a contract finishes varies across project types. Proportion γ of all projects have a high probability of ending after two periods, q_H, while the rest have a low probability of an early finish, q_L. In the beginning nobody knows the project type (delay-prone or not), so the prior probability that the project ends after two periods is:

$$q_0 = \gamma q_H + (1-\gamma)q_L.$$

If the project ends in two periods, the GP can reveal this information, in which case the project's payoff becomes public knowledge. The GP can also hide information about the project's progress, claiming that the project has not ended yet, and keeping the payoff unknown.[6] Intuitively, the 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. The payoff structure of long-term projects is depicted in Figure 1.

Short-term projects, in which investment I yields a gross payoff μ after one period. This project may also be interpreted as a “safe” restructuring of a risky long-term project.

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

Assumption 2 is a common practice of many VC funds. It means that at $t = 1$ the 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 is not crucial to the model, it simply allows us to ignore I, when comparing long-term and short-term projects.

At $t = 1$ the payoff of the short-term project (if there are any) is realized and distributed. For long-term projects, the GP learns **for sure** the project's value, which is V for good projects, and 0 for bad. 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's quality, $Prob(Good) = p$; as well as of the project's length, q_0. 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 get back their investment. The remaining part of the fund's claim is distributed between the partners (GP and LPs) according to the stakes they have and the holdings value. If the project has ended by $t = 2$ **and the 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 the LPs can still keep their stakes in the project. We assume that the GP sells his stakes either to the LPs or to outside investors at a price, π, they agree on. We assume that there is no information asymmetry between the LPs and the outside investors.

2.3 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. Thus, if a long-term project is started at $t = 0$, its expected payoff:

$$p\,(V - m) + (1 - p)\,\mu - m \tag{1}$$

must exceed that of starting the short-term project from the beginning (we assume zero interest rate):

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

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

$$V \geq (m + \mu)\,\frac{1 + p}{p}. \tag{2}$$

Assumption 3 *We assume that inequality (2) holds.*

Assumption 3 for all projects ensures that VC funds are economically viable.

3 Results

The main actor in this game is the GP, who holds a double informational advantage over the LPs. Thus we have to analyze his payoff structure first. As we have mentioned before, we ignore interaction effects between different projects in the investment portfolio and the question of the optimal portfolio size. Therefore, we assume that the 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 the 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.

If at $t = 1$ the GP continues a good project and provides monitoring m, then with probability q the project ends at $t = 2$ and its true value is revealed, and distributed according to the contract. With probability $(1 - q)$ the project remains unfinished and the GP is obliged to sell his stake. Let us denote the fair resale value of the project by π. This is the expected value on the unfinished project within an equilibrium. Once the GP receives the information about the project at $t = 1$, and has to decide on continuation, the first-period monitoring is a sunk cost and does not count. He does not take the investments into account either, since they are the same under all scenarios.[7] The expected profit for the GP depends on the quality of the project, its expected time to fruition, and on whether the GP monitors it. The payoffs are as follows:

q	Value	Monitoring	GP's Expected Payoff at $t = 1$
All	All	No	$\alpha\pi$
q_H	V	Yes	$\alpha\left[q_H V + (1 - q_H)\pi\right] - m$
q_L	V	Yes	$\alpha\left[q_L V + (1 - q_L)\pi\right] - m$
Short	Term	Project	$\alpha\mu$

(3)

The GP's payoff from adopting a short-term project is always $\alpha\mu$.

We assume that the fair price for an unfinished project, π, is the expected value of the project, conditional on the fact that it is unfinished, and thus crucially depends on the equilibrium strategies of the GP.[8] This implicitly assumes that outside investors are risk-neutral, and the market is competitive. Formally,

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

Notice that if all the unfinished projects are good, then $\Pr\{0\} = 0$ and $\pi = V$.

The first result of the paper shows that the first-best cannot be attained. Formally, we have:

Proposition 1 *When the unfinished projects are fairly priced, i.e.,* $\pi = \mathrm{E}\{value|no\ info\}$*, no equilibrium exists in which bad projects are terminated at* $t = 1$ *for sure.*
Proof. *Suppose that such an equilibrium exists. Since all bad projects are terminated and* $\Pr\{0\} = 0$*, by equation (4) we should have* $\pi = V$*. To induce termination of bad projects, the GP's payoff from their continuation should be less than his payoff from starting a safe project, i.e.,* $\pi \leq \mu$*, which implies that* $V \leq \mu$*. This in turn contradicts Assumption 3.* ■

The intuition behind this result is as follows. The short-term projects must be significantly less profitable than the long-term project, $\mu \ll V$, to justify the existence of the VC. The price of an unfinished project is a weighted average between V and zero, since some of the unfinished projects are necessarily good. The combination of the two is such that the the GP prefers to continue a bad project and sell it as an unfinished one, rather than aborting it in favor of a short-term project.

This is a very important result, because it shows that with fair pricing we always have inefficient outcomes. Efficiency can be improved either by modification of the GP's payoffs, or by changing the pricing mechanisms.

Next, let us check whether good projects are ever chosen to be continued at $t = 1$. If none of them are, then any unfinished project is worthless, i.e., $\pi = 0$, which creates a contradiction. This means that at least when $q = q_H$, the 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 that he stops monitoring and sells the project as an unfinished one. The following proposition defines the equilibria:

Proposition 2 *Let us denote:* $M \equiv \frac{m}{\alpha}$*. In the game described above there exist two types of equilibria in pure strategies:*

1. *For* M *satisfying*

$$M \leq \min\left\{q_L V \frac{1-p}{1-pq_0}, \frac{(pV-2\mu)}{(1+p)}\right\}, \tag{5}$$

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 $p(V-m)-m$.

2. *For* M *satisfying*

$$\min\left\{q_H V\frac{1-\gamma p}{1-\gamma p q_H},\frac{\gamma p V-2\mu}{(1+\gamma p)}\right\}\geq M>q_L V\frac{1-\gamma p}{1-\gamma p q_H}, \tag{6}$$

there exists an equilibrium, in which all projects are continued. Good projects that are delay-prone are not monitored. The expected total payoff of the VC in this case is $\gamma pV-m(1+\gamma p)$.

Proof: In the Appendix.

Comparing inequalities (19) and (22) it is easy to conclude that no M can satisfy both (5) and (6) at the same time. Some M, however, satisfy neither, suggesting mixed strategy equilibria.

Proposition 2 clearly separates the efficiency losses associated with each type of inefficiency. The equilibrium with the continuation of all good projects yields the total payoff of $p(V-m)-m$, which means that the efficiency loss relative to the first-best (1) is $\mu(1-p)$. This is the opportunity cost of the continuation of bad projects. The loss of efficiency in the equilibrium in which the delay-prone good projects are not monitored is $\mu(1-p)+(1-\gamma)p(V-m)$. The first component is the same as before, while the second component represents the cost of additional inefficiency due to the lack of monitoring of the good projects – arguably this is the large cost.

Finally, notice that an increase in μ and p, and a decline in q_L, α, and V reduce the region in which all good projects are monitored. The crash of Nasdaq in 2000 significantly reduced the valuations, V, and arguably increased the expected time to exit, i.e., lower q_L and q_H, and lower γ. This suggests that the likelihood of being in the inefficient equilibrium increased quite dramatically. There may have been a small offsetting effect if p declined as well. We plan to use this event for an empirical study of this model.

3.1 Magnitude of the efficiency loss

The paper focuses on the efficiency loss associated with this contractual provision. Here we would like to present the magnitude of the problem.

Recall that the first-best surplus obtained by the VC is

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

We include the term $2I$ here since it is important for the measurement of the relative efficiency loss. Yet we immediately set $I=1$, so as to interpret all the other parameters in percentage terms relative to the one-period investment. The relative loss of efficiency in the first equilibrium when all the good projects are monitored is:

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

The relative loss is increasing in m and μ, and decreasing in V and p.

Suppose that the expected return from the VC portfolio is around 40% per year (the denominator is therefore 0.8), that $p=0.1$, and that the short-term projects yield 10% return per year, i.e., $\mu=1.1$. Under these parameter values the magnitude of the relative loss due to the continuation of bad projects is on the order of a magnitude of $1.1\times 0.1/0.8=13.75\%$. This is a sizeable loss, which is mostly borne by the LPs.

The efficiency loss associated with the discontinuation of monitoring of good, but delay-prone, projects is $\gamma p\,(V-m)$, which implies that the relative loss is

$$\frac{(1-\gamma)p\,(V-m)}{p\,(V-m)+(1-p)\,\mu-m-2}.$$

The absolute loss of efficiency is increasing in m, while decreasing in μ and γ. The effects of V and p are ambiguous: if $(1-p)\,\mu-m-2\ <0$, the relative loss is declining in V and p.

Assuming the same parameter values as above, and adding the assumption that $m = 0.1$, implies that V should be on the order of a magnitude of 28 to yield the required rate of return (so that the denominator is 0.8). This puts the magnitude of the relative loss stemming from the discontinuation of good, but delay-prone, projects, at

$$\frac{0.269\gamma}{0.8} \cong 0.34(1-\gamma).$$

If the delay-prone projects constitute a large proportion of all projects (low γ), then the efficiency loss could be quite significant and outweigh the loss of efficiency due to the continuation of bad projects. Jointly, they are likely to constitute up to a **quarter** of the value that can be created by the VC under the firs best condition.

3.2 Special case

Looking at a special case may be helpful in emphasizing the source of the results. Suppose that all the projects are good, and this fact is common knowledge, which 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 still being terminated. Modifying Proposition 2 we immediately see that the equilibrium in which all good projects are continued is no longer viable; thus any pure strategy equilibrium involves inefficient termination of delay-prone projects. The intuition is straightforward: if all good projects are continued, the 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

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

For values of M higher than the LHS of the above inequality no VC funds ever exist, while for the lower M we obtain a mixed strategy equilibrium (see the Appendix). The results suggest that the inefficient abortion of the delay-prone projects is endemic, and does not depend on the first result.

4 Endogenous α

In previous sections we treated α as given, implicitly assuming that its value is mutually agreed upon by the LPs and the GP at $t = t_0$[9]. The model focused on the GP's strategy in continuing or terminating projects at $t = t_1$, considering α as an exogenous factor in the model. In this section we expand our analysis by incorporating the choice of α. We make the simplifying assumption that the LPs have all the bargaining power in choosing α. This is an innocuous assumption to make computations more straightforward. Giving more bargaining power to the GP will change results quantitatively, but not qualitatively.

Obviously, the LPs will choose the minimal α possible in each equilibria (since $m \geq 0$, this is equivalent to maximizing M[10]). In other words, for each strategy of the GP, the LPs will chose α that makes binding the equilibrium condition (5):

$$M = \min\left\{q_L V \frac{1-p}{1-pq_0}, \frac{(pV-2\mu)}{(1+p)}\right\}, \tag{7}$$

or (6)

$$M = \min\left\{q_H V \frac{1-p\gamma}{1-p\gamma q_H}, \frac{p\gamma V-2\mu}{(1+p\gamma)}\right\}. \tag{8}$$

The LPs' expected payoff is

$$S_1 = (1-\alpha)\, pV = \left(1 - \frac{m}{\min\left\{q_L V \frac{1-p}{1-pq_0}, \frac{(pV-2\mu)}{(1+p)}\right\}}\right) pV \tag{9}$$

in the pooling equilibria with monitoring of all projects, i.e., chosen α is such that equality (7) holds, or

$$S_2 = (1-\alpha)\,p\gamma V = \left(1 - \frac{m}{\min\left\{q_H V \frac{1-p\gamma}{1-p\gamma q_H}, \frac{p\gamma V - 2\mu}{(1+p\gamma)}\right\}}\right) p\gamma V \tag{10}$$

in the pooling equilibria with only in-time projects to be monitored, i.e., chosen α is such that equality (8) holds.

The LPs' payoffs for each strategy and optimally chosen α are shown in Figures 2 and 3, respectively, for the following values: $p = 0.5$, $V = 20$, $\mu = 1$, $q_0 = 0.5$, $\gamma = 0.5$, and $m = 1$. On Figure 2 the upper horizontal solid line represents the hypothetical payoff to LPs in the first-best outcome with $\alpha = 20\%$. The horizontal dotted line shows payoffs corresponding to (10) with $\alpha = 41.7\%$, chosen by the LPs to induce this equilibrium. The upward sloping dotted line indicates payoffs corresponding to (9) with α varying for each q_L to induce the pooling equilibrium with monitoring. For $q_L \leq 10.6\%$ the LPs prefer strategy S_2 that precludes monitoring delay-prone projects, and therefore will choose M according to expression (8), while for larger values of q_L they prefer strategy S_1 with monitoring of all projects, and will choose M satisfying (7). For $0.106 \leq q_L \leq 0.4$ α is decreasing in q_L, because the IC condition for the GP (to monitor delay-prone projects) is binding, while for $q_L > 0.4$ α becomes constant, because the condition on wether to undertake long-term projects becomes binding.

Sahlman (1990) claims that almost all LP-GP contracts have α set to 20%, and our inquiries suggest that this is still the norm in the industry. Our results clearly indicate that in this environment using the same carried interest for all types of projects is suboptimal, and induces inefficiency. Biotechnology should be financed under different contracts than the Internet startups, and both should be different from the contracts in the medical equipment field. By the same token, the carried interest should have changed after the events of 2000, because a significant increase in the expected time to exit warrants changes in the carried interest (perhaps combined with other contractual provisions, as described below). It is puzzling, therefore, to observe such low variation in α in reality.

5 Contract Design

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

5.1 Giving the GP a lower stake in the unfinished projects

Suppose that the GP gets a lower stake in all unfinished projects: we denote this 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 a debt contract that is contingent on the state of nature. Here as well, if the project is unfinished, the GP's contract is different from one for a finished project, which produces incentives for him to avoid the former state of nature.

To achieve the first-best would require that the GP terminate bad projects, which implies that $\mu > k\pi$, even though $\pi = V$.

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

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

Obviously, inequality (11) also implies that the GP never stops monitoring good projects if he decides to continue them. The question remains whether the GP would like to continue the delay-prone project or to replace it by the safe one. In fact he would continue iff

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

or

$$k \geq \frac{M + \mu - q_L V}{V\left(1-q_L\right)}. \tag{13}$$

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. Taking into account that $M = \frac{m}{\alpha}$ is monotonically decreasing in α and $\alpha \le 1$, from inequalities (11) and (13) we obtain the first necessary condition for the first-best outcome to exist:

$$q_L \ge \frac{m}{V-\mu}. \tag{14}$$

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

$$pq_0V + kp(1-q_0)V + (1-p)\mu - M(1+p) > 2\mu.$$

This gives the lower bound on k:

$$k \ge \frac{(1+p)(\mu+M)}{p(1-q_0)V} - \frac{q_0}{(1-q_0)}. \tag{15}$$

So, we have another inequality to hold in order to obtain the first-best:

$$q_0 \ge \frac{\mu + m\,(1+p)}{p\,(V-\mu)}. \tag{16}$$

If (11) holds, but (12) does not, the GP is expected to abandon the delay-prone projects. At $t = 0$ a similar condition is

$$p\gamma q_H V + kp\gamma(1-q_H)V + (1-p\gamma)\mu - M(1+\gamma p) > 2\mu,$$

$$k > \frac{(1+\gamma p)(\mu+M)}{p\gamma(1-q_H)V} - \frac{q_H}{(1-q_H)}, \tag{17}$$

where $M > V\left[q_L + k(1-q_L)\right] - \mu$.

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

$$\begin{aligned} &pV + (1-p)\mu && \text{if all good projects continue;} \\ &p\gamma V + (1-\alpha)(1-p\gamma)\mu && \text{if "in-time" projects continue.} \end{aligned}$$

The added value comes from two sources: first, termination of bad projects contributes the value of short-term projects times the probability of them being undertaken when the long-term project is bad. Second, the equilibrium yields the 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 above-mentioned policy, where $k = 0$. It may improve efficiency because it leads to early termination of all bad projects but the side effect of setting k to zero is that the first-best is achievable only if $M \leq Vq_L - \mu$ and

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

which specifies a narrower range of parameter values than the contractual provision suggested above.

5.2 GP keeps cash flow claims for unfinished projects

Another way of alleviating the problem is to extend the GP's interests in the unfinished projects beyond the end of the VC fund's life.[11] As pointed out above, the LPs limit the control rights of the GP to control for opportunistic behavior of the GP, but they should 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 these rights are not vested before that. The LPs will set z to the lowest level that ensures efficiency.

This provision ensures that the 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 $\pi = V$.

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

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

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

$$z > \frac{\mu + M}{(1 - q_L)V} - \frac{q_L}{(1 - q_L)}.$$

The 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 must be satisfied:

$$pq_0 V + zp(1 - q_0)V + (1 - p)\mu - M(1 + p) > 2\mu.$$

This gives another lower bound on z:

$$z > \frac{(1 + p)(\mu + M)}{p(1 - q_0)V} - \frac{q_0}{(1 - q_0)}.$$

Thus, as long as

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

the equilibrium attains the first-best, and yields a similar increase in the overall payoff for the fund as the contractual provision discussed above. Interestingly, while the two provisions impose opposing restrictions on the GP rights on unfinished projects, both yield a significant improvement in efficiency.

5.3 VC syndication

As a modification of the previous suggestion, a VC with a short time horizon may invest together with a younger (i.e., a different set $[q_H, q_L]$) 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 the 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.

6 Empirical Predictions

The emphasis in this paper is on pointing out the sources of inefficiency associated with the particular contractual provisions within the VC, and suggesting potential contractual amendments to alleviate or solve the problem. The model that accomplished these tasks also yields several empirical predictions, which we plan to test in the future. We outline these predictions in this section.

The first set of predictions has to do with the exogenous parameter changes and their effects on the behavior of the GP and the resulting changes in efficiency of the VCs. The structural change in this industry that was driven by the sharp decline in the Nasdaq index is a good example. It is widely accepted that this event resulted in the decline of the exit values, which were manifested either in lower V or in a lower proportion of good projects, p. At the same time there was an increase in the average time to exit, which in our model would imply that both q_L and q_H (and perhaps γ) declined. In addition, we believe that the range, $(q_H - q_L)$, increased as well. All these suggest that the misalignment of the GP's and the LPs' incentives increased after 2000, which would imply an increase in the proportion of good projects that were let go. One must be careful, however, since a good project that was abandoned is hard to differentiate from a bad project, and the proportion of the latter increased as well.

Another way to explore the effect of parameters is to focus on different segments of the industry that specialize in different technologies. If we are able to establish a connection between the technology and some of the parameter values, we may be able to test the predictions of the model with respect to its parameters.

We have shown that various contractual provisions may alleviate this problem. Adjusting the carried interest, α, to the specific environment of the VC; reducing (or eliminating) the GP's stake in the unfinished projects; letting the GP keep cash rights in the unfinished projects; or establishing syndicates between VCs of varying age - all should reduce the degree of inefficiency. If we can obtain the data on the relevant contractual provisions for a sample of VCs, we can then relate these to the proportion of their projects that are abandoned or left unfinished. In addition, we can predict and test the degree of the effect of the 2000 crash on these funds. Those with the appropriate contractual provisions should be less affected than those that stick to the industry standards.

Finally, we are planning to test whether the changes in the contractual provisions post-2000 are consistent with the fact that the problem we describe became much more acute.

7 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, the inefficient continuation of bad projects is almost sure, while in many cases the inefficient termination of good projects 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's life, which is a controlling device to solve agency and informational asymmetry problems between the GP and the LPs. We developed a simple model that reveals the suboptimal nature of continuation/write-off decisions a few years before the fund's maturity. We show that both selling unfinished projects at competitive "fair" price and termination of all unfinished projects at the fund's maturity create suboptimal outcomes, although of a different nature. A VC fund, in which the 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 a much higher quality of the portfolio, but this result comes at the cost of writing-off some good projects long before the fund's maturity.

We propose several contractual remedies: lower stakes in 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.

The model generates several empirical implications: the misalignment of the GP's and the LPs' incentives (and consequently the loss of efficiency) increased in the "post-bubble" period, due to structural changes in exogenous parameters influencing the GP's behavior. Moreover, VC funds that write off all the unfinished projects, or allow the GP's to maintain cash flow rights in unfinished projects, should exhibit a higher average quality of projects, and better profitability. Syndicates of VC funds of different age have a lower termination rate of good projects than more homogeneous syndicates. However, the proportion of successful exits decrease with the age of the VC fund. 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 and on projects belonging to different industry/technology segments.

8 Figure Legends

Figure 1 shows the long-term project payoff to VC fund. One period before the fund's maturity the GP observes the project's quality(the payoff to the fund is V for a good project and 0 for a bad one) and the probability q of its ending by the fund's maturity. The 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 payoff to the fund μ. π is the expected value of the project of unknown quality, given that its value is unknown or undisclosed.

Figure 2 shows the LPs' payoffs for each strategy and optimally chosen α for the following parameter values: $p = 0.5$, $V = 20$, $\mu = 1$, $q_0 = 0.5$, $\gamma = 0.5$ and $m = 1$. The upper horizontal solid line represents hypothetical payoffs to the LPs in the first-best outcome with $\alpha = 20\%$, the horizontal dotted line shows payoffs corresponding to (10) with $\alpha = 41.7\%$, chosen by the LPs to induce this equilibrium, and the upward sloping dotted line indicates payoffs corresponding to (9) with α varying for each q_L to induce the pooling equilibrium with monitoring.

Figure 3 shows optimally chosen α for the following parameter values: $p = 0.5$, $V = 20$, $\mu = 1$, $q_0 = 0.5$, $\gamma = 0.5$, and $m = 1$. Kink corresponds to the switch from one pooling equilibrium to another.

Figure 4 compares optimally chosen α in the case of fair (linear) pricing (dotted line) and in the case of restoring the first best by giving the GP different stakes in successful (α) and uncertain ($k\alpha$) projects (solid line). The parameter values are: $p = 0.5$, $V = 20$, $\mu = 1$, $q_0 = 0.5$, $\gamma = 0.5$ and $m = 1$. $k = \frac{\mu}{V} = 0.05$. The first-best result is possible only for $q_L > 0.05$.

Figure 5 compares the LPs' payoffs in linear payoff (dash-dotted line) and non-linear payoff restoring the first best outcome. The parameter values are: $p = 0.5$, $V = 20$, $\mu = 1$, $q_0 = 0.5$, $\gamma = 0.5$, and $m = 1$. The GP's payoff (dotted) line is given for illustrative purposes.

A Appendix.

A.1 Proof of Proposition 2

Equilibrium with monitoring of all good projects

If all good projects are monitored, then from an outsider's prospective, an unfinished project can be a bad project with probability $(1-p)$, it can be a good, but delay-prone, project with probability $p(1-\gamma)(1-q_L)$, and with probability $p\gamma(1-q_H)$ it can even be a good project that is not delay-prone. Therefore, the probability of observing an unfinished project is $1-pq_0$. 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

$$\pi_1 = V\frac{p\,(1-q_0)}{1-pq_0}. \tag{18}$$

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

The 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 and using the notation $M = \frac{m}{\alpha}$, we obtain the first condition:

$$M \leq q_L\,(V-\pi_1) = q_L V\frac{1-p}{1-pq_0}. \tag{19}$$

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:

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

Rearranging and substituting π_1, we get

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

Thus this equilibrium exists whenever

$$M \leq \min\left\{q_L V \frac{1-p}{1-pq_0}, \frac{(pV-2\mu)}{(1+p)}\right\}. \tag{20}$$

Total payoff calculation: The GP expects to receive a payoff of $\alpha V\left\{q_i + (1-q_i)\frac{p(1-q_0)}{1-pq_0}\right\} - m$ from a good project, which has a probability of finishing in time equal to q_i, $i = \{L, H\}$. From a bad project he expects to receive a payoff of $\alpha V \frac{p(1-q_0)}{1-pq_0}$. So, at $t = 0$ his expected net payoff from the long-term project is $p\alpha V - m(1+p)$.

The LPs, who at $t = 1$ do not know the true state and updated probability q, expect to receive a payoff of:

$$V - \alpha V\left\{q + (1-q)\frac{p(1-q_0)}{1-pq_0}\right\}$$

from a good project and

$$-\alpha V \frac{p(1-q_0)}{1-pq_0} - 2(1-\alpha) I$$

from a bad project. Their expected net payoff is $pV(1-\alpha)$.

Equilibrium with no monitoring of delay-prone projects

Since monitoring in this equilibrium is continued only for good projects with a high probability of finishing at $t = 2$, 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 $q = q_H$:

$$\pi_2 = V\left(\frac{1-q_H}{1-p\gamma q_H}\right)p\gamma. \tag{21}$$

Since $\gamma q_H < q_0 < q_H$, it follows immediately that $\pi_2 < \pi_1$.

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

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

which gives us the double inequality for M:

$$q_L\left(V - \pi_2\right) < M \leq q_H\left(V - \pi_2\right) \tag{22}$$

Substituting the value of π_2 we get

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

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 $M \leq \frac{p\gamma V - 2\mu}{(1+p\gamma)}$.

Thus the conditions for the existence of the equilibrium with the inefficient termination of delay-prone good projects is

$$\min\left\{q_H V \frac{1 - p\gamma}{1 - p\gamma q_H}, \frac{p\gamma V - 2\mu}{(1 + p\gamma)}\right\} \geq M > q_L V \frac{1 - p\gamma}{1 - p\gamma q_H}. \tag{23}$$

Total payoff calculation: The GP expects to receive from a good project with $q = q_H$ a payoff of

$$\alpha V \left(q_H + \frac{\gamma p \left(1 - q_H\right)^2}{1 - \gamma p q_H} \right) - m.$$

In all other cases he expects to receive $\alpha V \gamma p \frac{p(1-q_H)}{1-\gamma p q_H}$. So, at $t = 0$ his expected net payoff from the long-term project is

$$\alpha \left[p\gamma q_H V + (1 - p\gamma q_H) V \left(\frac{1 - q_H}{1 - p\gamma q_H} \right) p\gamma \right] - m(1 + p\gamma)$$
$$= \gamma \alpha p V - m \left(1 + \gamma p\right).$$

The LPs' expected net payoff is $\gamma p V \left(1 - \alpha\right)$. The combined expected payoff to both the GP and the LPs is $\gamma p V - m \left(1 + \gamma p\right)$. **QED**.

A.2 Mixed Strategies

There might exist mixed strategy equilibria, in which all the good projects are continued, while bad projects are sometimes (randomly) continued as well. Let us denote by θ the probability that a bad project is continued. Then it must be that $\pi = \mu$, since for $\pi > \mu$ all bad projects are continued while for $\pi < \mu$ all are terminated. 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

$$\pi_3 = V \frac{p\,(1-q_0)}{p(1-q_0)+\theta(1-p)} = \mu. \tag{24}$$

This implies that the equilibrium value of θ i

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

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

The 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:

$$M \leq q_L(V-\mu)$$

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:

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

Rearranging we get

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

Thus, this equilibrium exists whenever

$$M \leq \min\left\{ q_L(V-\mu), \frac{pq_0 V - (1+pq_0)\mu}{(1+p)} \right\}$$

Similarly, we can derive a mixed strategy equilibrium in which the GP randomly stops monitoring delay-prone projects

Let us denote by ϕ the probability that a delay-prone project is monitored. Then, $(1-\phi)$ is the probability that it becomes a bad project. The GP should be indifferent between continuing the monitoring and not monitoring. Therefore, we have

$$\pi_4 = q_L V + (1-q_L)\,\pi - M,$$

where the right-hand side is the expected payoff with monitoring and the left-hand side — without monitoring. Rearranging, we have that in equilibrium

$$\pi_4 = V - \frac{M}{q_L}. \tag{25}$$

We also have the following probabilities:

$$\begin{aligned}
\Pr\left[unfinished|good\right] &= \frac{\gamma}{\gamma+(1-\gamma)\,\phi}\,(1-q_H) + \frac{(1-\gamma)\,\phi}{\gamma+(1-\gamma)\,\phi}\,(1-q_L)\,; \\
\Pr\left[good\right] &= p\left[\gamma+(1-\gamma)\,\phi\right]; \\
\Pr\left[unfinished|bad\right] &= 1; \\
\Pr\left[bad\right] &= 1-p+p\,(1-\gamma)\,(1-\phi)\,.
\end{aligned}$$

Using expression (4) for competitive pricing, we find the conditional expected value of an unfinished project to be equal to

$$\begin{aligned}
\pi_4 &= V\frac{\Pr\left[unfinished|good\right]\Pr\left[good\right]}{\Pr\left[unfinished|good\right]\Pr\left[good\right]+\Pr\left[unfinished|bad\right]\Pr\left[bad\right]} \\
&= V\frac{\left[\gamma\,(1-q_H)+(1-\gamma)\,\phi\,(1-q_L)\right]p}{\left[\gamma\,(1-q_H)+(1-\gamma)\,\phi\,(1-q_L)\right]p+1-p+p\,(1-\gamma)\,(1-\phi)}.
\end{aligned}$$

Using (25) we find that

$$\phi = \frac{q_L V (1 - p\gamma) - M (1 - p\gamma q_H)}{p q_L (V - M)(1 - \gamma)}$$

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

The first condition means that for in-time projects it is always optimal to continue monitoring and for bad projects it is always optimal to continue them. While the first is obvious because of $q_H > q_L$, for the second we have to verify that

$$V - \frac{M}{q_L} > \mu$$
$$M < q_L (V - \mu).$$

The second condition (investment at $t = 0$) means that

$$(p(\gamma(1 - q_H) + (1 - \gamma)(1 - \phi + \phi(1 - q_L))) + 1 - p)\left(V - \frac{M}{q_L}\right) +$$
$$+ p(\gamma q_H + (1 - \gamma)\phi q_L) V - M(1 + p(\gamma + (1 - \gamma)\phi)) > 2\mu$$

$$M < q_L \frac{V - 2\mu}{1 + q_L(1 + \gamma p) - \gamma p q_H}.$$

So, for this equilibrium to exist, inequality

$$M < q_L \min\left\{V - \mu, \frac{V - 2\mu}{1 + q_L(1 + \gamma p) - \gamma p q_H}\right\}$$

must hold.

A.3 Endogenous α and k

Suppose that at $t = 0$ the LPs are allowed to choose α and k simultaneously to maximize their expected payoff:

$$\max_{\alpha,k} \left(pV \left(\left(1 - \alpha q_0 \left(1 - k \right) \right) \right) + \left(1 - p \right) \left(1 - \alpha \right) \mu \right) \tag{26}$$

subject to (11) and (13), if (14) and (16) hold. It is easy to verify that (26) is increasing in k and decreasing in α, thus making both (11) and (13) binding. Therefore, if (14) and (16) hold, $k^{opt} = \frac{\mu}{V}$ and $\alpha^{opt} = \frac{m}{q_L(V-\mu)}$ and the LPs' payoff is equal to

$$p \left(V - m \frac{q_0}{q_L} \right) + (1-p) \left(1 - \frac{m}{q_L \left(V - \mu \right)} \right) \mu.$$

In Figure 4 we compare optimally chosen α in the case of fair pricing (dotted line) and in the case of restoring the first-best by giving the GP different stakes in successful (α) and uncertain ($k\alpha$) projects (solid line). The parameter values are: $p = 0.5$, $V = 20$, $\mu = 1$, $q_0 = 0.5$, $\gamma = 0.5$, and $m = 1$. $k = \frac{\mu}{V} = 0.05$. Due to (15), the first-best result is attainable only for $q_L > 0.05$. We see that a lower payoff to the GP in uncertain outcome restores the first-best result without giving the GP too many of the stakes in the project. Figure 5 illustrates the LPs' payoffs in these cases. Notice, that if the LPs had followed the common practice of constant carried interest $\alpha = 20\%$, then their payoff in the first-best scenario would have been equal to only 8.4 (see Figure 2), while our contract design allows them to obtain higher payoffs, if q_L is high enough.

The unattainability of the first-best outcome for low q_L and the GP's payoff decreasing in q_L give the GP an incentive to choose portfolios of projects with a very high variability of probability of finishing in time.

References

Admati, A.R. and P. Pfleiderer, "Robust Financial Contracting and the Role of Venture Capital," *Journal of Finance*, 1994, *49* (2), 371–402.

Aghion, Philippe et al., "Exit Options in Corporate Finance: Liquidity versus Incentives," *European Finance Review*, 2004, *8*, 1–27.

Bai, Chong-En and Yijiang Wang, "Agency in Project Screening and Termination Decisions: Why is Good Money Thrown After Bad?," 1998. SSRN.

Benmelech, Efraim, "Asset Salability and Debt Maturity: Evidence from 19th Century American Railroads," 2004.

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

Casamatta, Catherine, "Financing and Advising: Optimal Financial Contracts with Venture Capitalists," June 2000. Working paper.

—— **and Carole Haritchabalet**, "Learning and Syndication in Venture Capital Investments," May 2003. CEPR Working Paper 3867.

Cumming, D. and J. MacIntosh, "Economic and Institutional Determinants of Venture Capital Investment Duration," 2001. Working paper.

Dewatripont, M. and E. Maskin, "Credit and Efficiency in Centralized and Decentralized Economies," *Review of Economic Studies*, October 1995, *62*, 541–555.

Diamond, Douglas, "Financial Intermediation and Delegated Monitoring," *Review of Economic Studies*, 1984, *51*, 393–414.

Gompers, Paul, "Optimal Investment, Monitoring and the Staging of Venture Capital," *Journal of Finance*, December 1995, *50* (5), 1461–1489.

——, "Grandstanding in the Venture Capital Industry," *Journal of Financial Economics*, 1996, *42*, 133–156.

—— **and Josh Lerner**, "The Use of Covenants: An Empirical Analysis of Venture Partnership Agreements," *The Journal of Law and Economics*, October 1996, *39*, 463–498.

—— **and** ——, "An Analysis of Compensation in the U.S. Venture Capital Partnership," *Journal of Financial Economics*, January 1999, *51* (1), 3–44.

Hellmann, Thomas, "The Allocation of Control Rights in Venture Capital Contracts," *The Rand Journal of Economics*, Spring 1998, *29* (1), 57–76.

——, "A Theory of Strategic Venture Investing," *Journal of Financial Economics*, May 2002, *64* (2), 285–314.

Kanniainen, Vesa and Christian Keuschnigg, "The Optimal Portfolio of Start-Up Firms in Venture Capital Finance," December 2000. CESifo Working Paper No. 381.

Kaplan, Steven and Per Stromberg, "Characteristics, Contracts, and Actions: Evidence From Venture Capital Analyses," January 2002. Working Paper.

—— **and** ——, "Financial Contracting Theory Meets the Real World: An Empirical Analysis of Venture Capital Contracts," *Review of Economic Studies*, 2003, *70* (2), 281–315. Working Paper.

Lerner, Josh, "Venture Capitalists and the Oversight of Private Firms," *Journal of Finance*, March 1995, *50* (1), 301–318.

—— **and Antoinette Schoar**, "The Illiquidity Puzzle: Theory and Evidence from Private Equity," *Journal of Financial Economics*, 2004, *72*, 3–40.

Leshchinskii, Dima, "Project Externalities and Moral Hazard," 2002. Working Paper.

Malherbe, E., "Modeling Private Equity Funds and Private Equity Collateralized Fund Obligations," 2003. Working Paper.

Neher, D., "Staged Financing: An Agency Perspective," *Review of Economic Studies*, 1999, *66* (2), 255–274.

Qian, Yingyi and Chenggang Xu, "Innovation and Bureaucracy Under Soft and Hard Budget Constraints," *Review of Economic Studies*, 1998, *65*, 151–164.

Repullo, Rafael and Javier Suarez, "Venture Capital Finance: A Security Design Approach," *European Finance Review*, 2004, *8* (1), 75–108.

Sahlman, W., "The Structure and Governance of Venture Capital Organization," *Journal of Financial Economics*, 1990, *27*, 473–521.

Notes

[1]Bergemann and Hege (1998), Repullo and Suarez (2004) and Casamatta (2000) are just a few examples of studies of (dual) moral hazard in VC - entrepreneur relations. Kaplan and Stromberg (2003) 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 Gompers (1996), Gompers and Lerner (1996), Gompers and Lerner (1999) and Lerner and Schoar (2004), who study partnership agreements in VC partnesrhips and private equity funds and Aghion et al. (2004), who study theoretically optimal design of exit options for active monitors' (GPs).

[3]For example, in the Bai and Wang (1998) model, to induce the agent's effort to gather information about the projects, the optimal incentive contract should impose restrictions on the starting and termination of projects, leading to the ex-post inefficient continuation of bad projects, unlike Dewatripont and Maskin (1995), where continuation was ex-post efficient (the paper offers an answer to the question of how capitalist economies succeed in hardening soft-budget constraints) Qian and Xu (1998) show that a multiplicity of financiers can help constrain refinancing at the cost of increased monitoring.

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

[5]Although this assumption appears to impose a "non-credible" restriction, it is largely accepted in the literature; see, e.g., Gompers (1995).

[6]Whether the GP can hide the project's progress or its status and payoff become publicly known depends on the nature of the project itself. We can imagine that some outcomes are easier to hide than others. We assume that for early-stage projects VC can easily conceal its progress. If one assumes 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.

[7]Again, we are not imposing a positive profit constraint. One might think that we assume unlimited liability here, but we simply assume that the pool of projects is profitable enough to compensate for the possible loss in one project — an argument similar to Diamond (1984).

[8]It is possible to imagine a situation, in which $\pi \neq \mathrm{E}\{value|\text{no information revealed}\}$. For example, at $t = 0$ the GP can sell the LPs a forward contract with a predetermined price π on all unfinished at $t = 2$ projects. This pricing can possibly improve the efficiency of the GP's decision concerning the project's termination/continuation by creating a commitment mechanism to terminate bad projects. We will show rationale for that in Section 3.

[9]Interestingly, in almost all LP-GP contracts, α is set to 20% (Sahlman (1990)). However, our model sugests that a rational LP should choose α to minimize the inefficiency zone, therefore varying across types of projects.

[10]If $m = 0 \Rightarrow M = 0, \forall\alpha$. Intuitively, this defines the VC's role as financial intermediary: without a specific monitoring cost involved, there is no reason for LPs to divert the α fraction to the GP, who, as result, cannot raise the fund.

[11]Without separation of control and cash flow rights, keeping the stake in the project induces certain cost on the GP (liabilities, reputation, signaling, etc.) which are not covered by management fees after the fund end. Consequently, it is optimal for the GP to keep such stakes only in high value projects with low probability of delay and this is what indeed

happens in reality. However, if only the cash claims are preserved after the fund end, the GP becomes a passive investor similar to the LPs and the conflict of interests disappears.

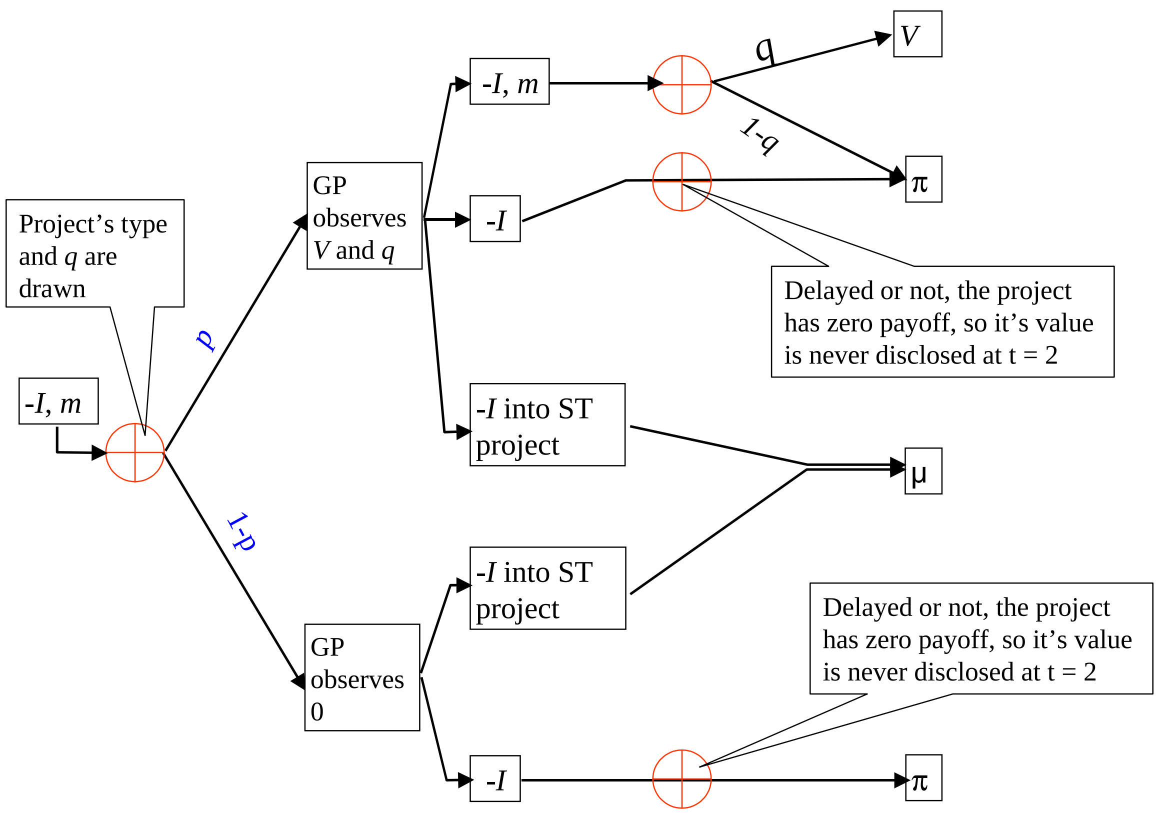

Figure 1: Long-term project payoff to VC fund. One period before the fund's maturity the GP observes the project's quality(the payoff to the fund is V for a good project and 0 for a bad one) and the probability q of its ending by the fund's maturity. The GP must decide – whether to continue investment I and monitoring m of the project or to replace it by a short term project with investment I and payoff to the fund μ. π is the expected value of the project of unknown quality, given that its value is unknown or undisclosed.

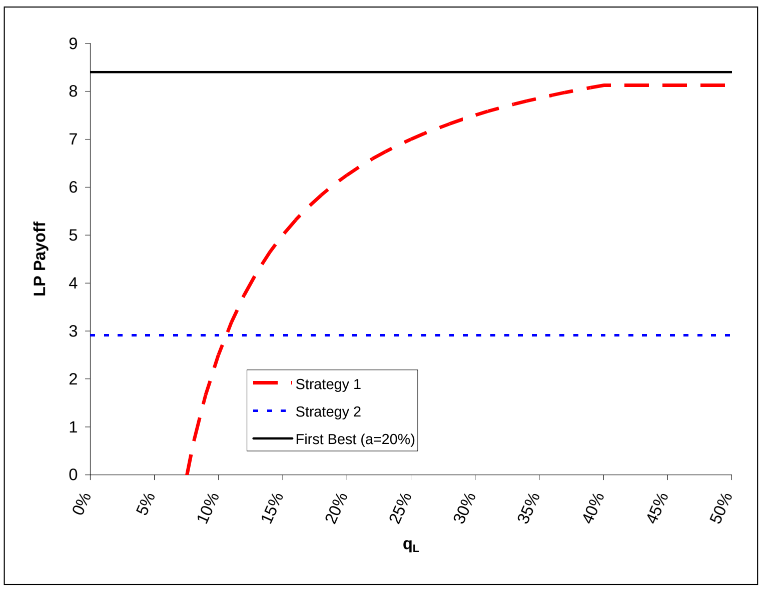

Figure 2: *This figure shows the LPs' payoffs for each strategy and optimally chosen α for the following parameter values: $p = 0.5$, $V = 20$, $\mu = 1$, $q_0 = 0.5$, $\gamma = 0.5$ and $m = 1$. The upper horizontal solid line represents hypothetical payoffs to the LPs in the first-best outcome with $\alpha = 20\%$, the horizontal dotted line shows payoffs corresponding to (10) with $\alpha = 41.7\%$, chosen by the LPs to induce this equilibrium, and the upward sloping dotted line indicates payoffs corresponding to (9) with α varying for each q_L to induce the pooling equilibrium with monitoring.*

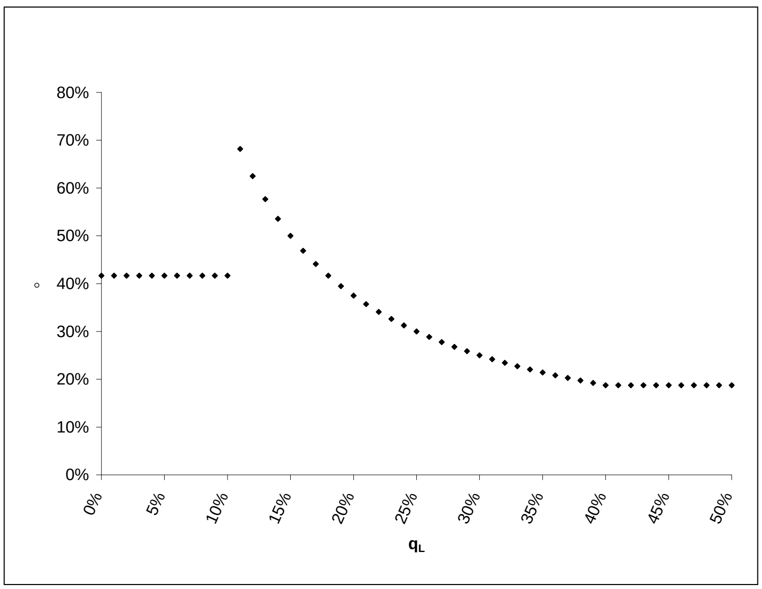

Figure 3: *This figure shows optimally chosen α for the following parameter values: $p = 0.5$, $V = 20$, $\mu = 1$, $q_0 = 0.5$, $\gamma = 0.5$, and $m = 1$. Kink corresponds to the switch from one pooling aquilibrium to another.*

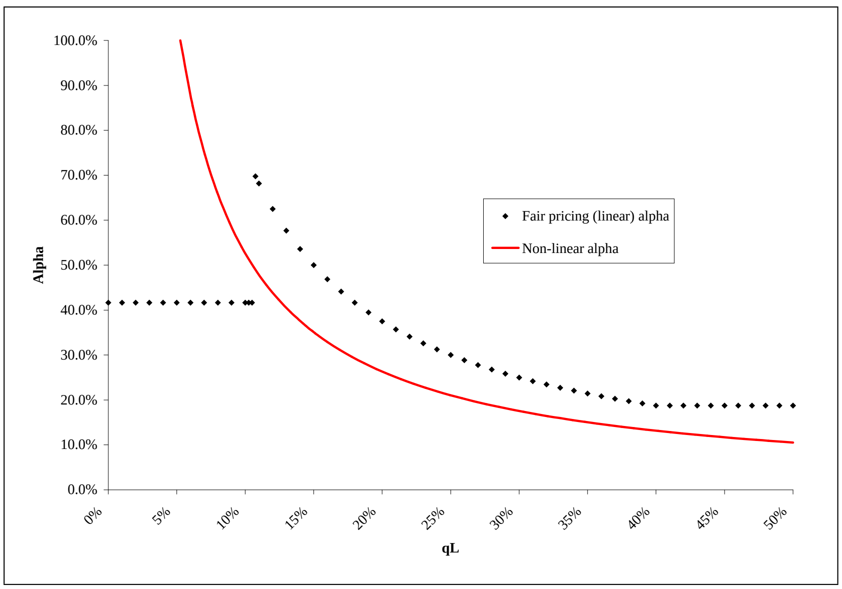

Figure 4: *This figure compares optimally chosen α in the case of fair (linear) pricing (dotted line) and in the case of restoring the first best by giving the GP different stakes in successful (α) and uncertain ($k\alpha$) projects (solid line). The parameter values are: $p = 0.5$, $V = 20$, $\mu = 1$, $q_0 = 0.5$, $\gamma = 0.5$ and $m = 1$. $k = \frac{\mu}{V} = 0.05$. The first-best result is possible only for $q_L > 0.05$.*

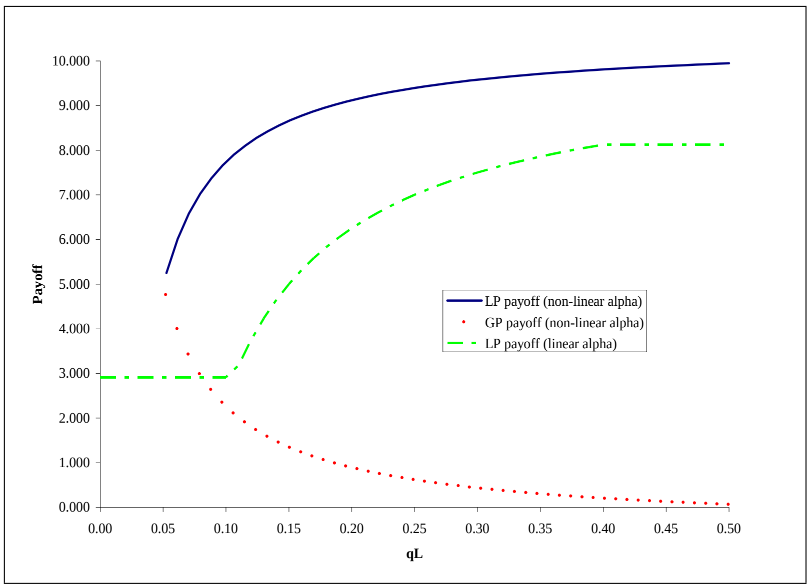

Figure 5: *This figure compares the LPs' payoffs in linear payoff (dash-dotted line) and non-linear payoff restoring the first best outcome. The parameter values are:* $p = 0.5$, $V = 20$, $\mu = 1$, $q_0 = 0.5$, $\gamma = 0.5$, *and* $m = 1$. *The GP's payoff (dotted) line is given for illustrative purposes.*

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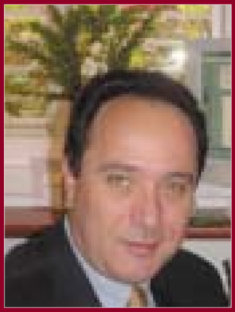

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