Essays on corporate finance under information asymmetry

Ph.D. Thesis of

Xuewen Liu

(LSE ID: 200203775)

Ph.D. in Accounting and Finance

London School of Economics

April 2007

I declare that the work presented in the thesis is my own.

Abstract

Essay 1: Stage Financing and Syndication in Venture Capital Investment

The combined use of stage financing and syndication is one of the most remarkable characteristics of venture capital financing. In particular, the majority of later-stage venture capital investments rather than early-stage are syndicated. The paper presents a theoretical rationale for this financial arrangement. The model shows that tight control (i.e. efficient refinancing or continuation/liquidation decision) of the venture capitalist by stage financing can achieve ex-post efficiency but may disincentivize the entrepreneur's effort provision ex-ante. Hence, the project value is not maximized. I show that the combined use of later-stage syndication with stage financing is a mechanism that can realize the optimal tradeoff between high effort ex ante and efficient continuation ex post thus maximizing project value. The model offers testable empirical predictions.

Essay 2: The Capital Structure of Private Equity-backed Firms

In this paper I study one fundamental tension between venture capitalist and management in private equity-backed firms and show capital structure (of private equity-back firms) is a mechanism to resolve the tension. The paper gives rationale for several financial arrangements in private equity investment. (1) Private equity deals are typically partially outside financed even though the private equity fund may not be financially constrained at the deal level. (2) The optimal security for outside financing is debt. (3) The maturity of outside security is long-term. The insight of the paper has applications outside of private equity.

Essay 3: Market Transparency and the Accounting Regime

We model the interaction of financial market transparency and different accounting regimes. This paper provides a theoretical rationale for the recently proposed shift in accounting standards from historic cost accounting to marking to market. The paper shows that marking to market can provide investors with an early warning mechanism while historical cost gives management a "veil" under which they can potentially mask a firm's true economic performance. The model provides new explanations for several empirical findings and has some novel implications. We show that greater opacity in financial markets leads to more frequent and more severe crashes in asset prices (under a historic-cost-accounting regime). Moreover, our model indicates that historic cost accounting can make the financial market more rather than less volatile, which runs counter to conventional wisdom. The mechanism shown in the model also sheds light on the cause of many financial scandals in recent years.

Contents

Stage Financing and Syndication in Venture Capital Investment*

Xuewen Liu

London School of Economics

This version: April, 2007

Abstract

The combined use of stage financing and syndication is one of the most prevalent features of venture capital financing. In particular, syndication is more likely to take place at a later stage. The paper presents a theoretical rationale for this financial arrangement. The model shows that tight control (i.e. efficient refinancing or continuation/liquidation decision) of the venture capitalist by stage financing can achieve *ex-post* efficiency but may disincentivize the entrepreneur's effort provision *ex-ante*. Hence, the project value is not maximized. I show that the combined use of later-stage syndication with stage financing is a mechanism that can realize the optimal tradeoff between high effort ex ante and efficient continuation ex post thus maximizing project value. The model offers testable empirical predictions.

JEL classification: G24, G30, G32, G33, D82.

Keywords: Stage financing; Syndication; Refinancing; Continuation; Liquidation.

*I am grateful to David Webb, Antoine Faure-Grimaud, Hyun Song Shin, Francesca Cornelli, Denis Gromb, Tianxi Wang, Alexander Bleck, Sridhar Arcot, Carsten Bienz and seminar participants at LSE for helpful comments. This paper is previously circulated under the title "Stage Financing and the Role of Syndication". Contact address: Financial market group, LSE, Houghton Street, London WC2A 2AE. Email: X.liu@lse.ac.uk.

Venture capital financing exhibits great risk and associates with severe informational and incentive problems. Three financial arrangements, which are common to nearly all venture capital financing, are the main tools employed by venture capitalists to deal with the special nature of investment: 1) the use of convertible securities, 2) syndication in investment and 3) the staging of capital infusions.[1] In the past few years a large literature has developed that studies many aspects of these financial arrangements. Yet our understanding of the role of and the relationships between these financial tools is far from complete. In this paper, I focus on two: syndication and stage financing. I examine how syndication interplays with stage financing and offer a rationale for the combined use of them in venture capital financing.

Sahlman (1990) notes that staged capital infusion is the most potent control mechanism that a venture capitalist can employ. Financing and investment are made in stages. The stages match up with business milestones, such as a demonstration of technology or a successful product introduction. Based on the new released information about the venture at every stage, the venture capitalist has the option to abandon the venture whenever the forward looking net present value of the project is negative (Cornelli and Yosha (2002)). Considering that an entrepreneur will almost never quit a failing project himself as long as others are providing capital (Admati and Pfleiderer (1994)), stage financing is particularly important. It functions as an efficient control mechanism for the venture capitalist to liquidate any unpromising project. That is, through stage financing, the venture capitalist can achieve (ex-post) control efficiency.

In this paper, however, I explore the negative side of stage financing. In fact, the ex-post efficient action is not necessarily ex-ante efficient. The tight *ex-post* control through stage financing may disincentivize the effort provision by entrepreneur *ex-ante*, which in turn lowers the overall value of the project. This argument is much in analogue with the one in Burkart, Gromb and Panunzi (1997), where tight ex-post ownership control disincentivizes the manger to provide effort ex-ante.

In fact, the sequential refinancing decision in staging gives rise to a fundamental tension between an entrepreneur's effort and lack of commitment by the venture capitalist. The entrepreneur exerts effort *first* and the venture capitalist makes her refinancing or continuation/liquidation *afterwards*.

[1] See Gompers (1995).

(Note: stage financing implicitly gives the investor the right to decide about the continuation or liquidation of the project). The entrepreneur obtains a private benefit from continuation. Quite naturally the entrepreneur exerts higher effort if and only if he anticipates that there will be a higher probability of continuation after making the effort. Also, the entrepreneur's effort is valuable to the venture capitalist in that it can increase the overall value of the project. In order to encourage the entrepreneur to exert efforts ex-ante, the venture capitalist should commit to continuing the project more often than is efficient ex-post, considering that the project is exposed to huge external risk beyond the control of the entrepreneur (e.g. uncertainty about the market condition of an IPO or a new product).[2] Therefore, there is a tradeoff between *high effort* and *efficient continuation* in maximizing the project value of the second-best.[3] However, in the world of incomplete contracting,[4] once the entrepreneur's effort is sunk, the venture capitalist maximizes her own utility by continuing the project only if it is worth it (i.e. only if continuation is profitable). Anticipating this behavior by the venture capitalist, the entrepreneur may choose an effort level that is lower than second best. That is, pure stage financing disincentivizes the entrepreneur's ex-ante effort provision. The second-best is not attainable.

The novelty of my paper lies in showing that the combined use of (later-stage) syndication with stage financing is a mechanism that can solve the tension, which can implement the second best. In other words, by using later-stage syndication, the lead venture capitalist commits to the second-best continuation decision that maximizes project value. As for why syndication can induce the commitment, the mechanism is in the same spirit as Myers and Majluf (1984). The authors of

[2] Venture capitalists and founders may face risks that are equally uncertain for both parties. Kaplan and Stromberg (2004) denote such uncertainties as external risks. Examples are the extent of future demand for an undeveloped product, the response of competitors upon the product's introduction, and the receptivity of financial markets when investors try to sell the company or bring it public.

In contrast, internal risk refers to uncertainties about which the entrepreneur is better informed than the venture capitalist. It relates to asymmetric information and is the main cause of agency problems.

[3] "Second-best" is in the sense that there is still the agency problem of unobservable effort of the entrepreneur.

[4] There are two forms of stage financing in reality: round financing and milestone financing. Round financing means that every new tranche is negotiated separately when the venture needs further funding; milestone financing requires that exact contingencies that the firm has to achieve to obtain new funds are fixed in the initial contract (Bienz and Hirsch (2005)). In my setting, as the entrepreneur and venture capitalist are not able to write or not profitable to write a complete contract to specify the terms of future financing, the milestone financing is not feasible. Staging financing in my paper is round financing.

that paper show external financing under asymmetric information leads to the bad project being pooled with the good project and therefore the (unprofitable) bad project may get financed. In my context, syndication is 'external financing' as the syndicate members are usually much less informed of the state of the project than the lead venture capitalist.[5] The information asymmetry between the lead venture capitalist and the syndicate members will necessarily lead to a similar inefficient pooling, i.e. the unprofitable project with a low state of nature may get *refinanced* and thus continued. That is, the lead venture capitalist is induced to continue the project *automatically* more often than if the project is fully inside financed without syndication.[6] Such a decision bias is not ex-post efficient (i.e. project with *negative* forward-looking NPV may be continued), but is useful to give incentive to the entrepreneur ex-ante. That is, stage financing with later-stage syndication can maximize the firm value.

An important empirical implication of the result is that syndication closely associates with stage financing. In fact, from the analysis above, if there is no staging, there may not be any syndication at all. More specifically, the model implies that the later-stage venture capital investment involves syndication. The predication is well supported by venture capital data. The evidence in Hopp (2006) shows that VC firms that make use of staging are also more open to syndication. Lerner (1994) finds that with a few exceptions all later-stage venture capital investments are syndicated in his sample of 271 private biotechnology firms. Fenn, Liang and Prowse (1997) document that the later-stage venture capital investments are often syndicated. Conversely, early-stage new ventures are more likely to be financed entirely by a single partnership. Furthermore, the model of this paper indicates that later-stage syndication occurs when the contingencies to obtain further new funding are not contracted initially, such as in round financing rather than in milestone financing. The evidence in Bienz and Hirsch (2005) supports this prediction. The authors find that outside

[5] Axelson, Stromberg and Weisbach (2005) write: "venture deals are often syndicated, with a lead venture capitalist raising funds from partners, who presumably take account of, at a minimum, information on the state of the economy and industry in the same way that banks providing financing to buyouts do."

[6] Inderst and Müller (2006), which studies credit analysis and decisions, also shows that the information asymmetry can lead to the agent's endogenous decision bias. One of key differences, however, is that the borrower has information advantage in my model while in Inderst and Müller (2006)'s model it is the lender. Of course, the main difference lies in that two papers study different questions and there do not exist any moral hazard issues in that paper. This difference also distinguishes my paper with Inderst and Müller (2004) which studies banks' loan decision and does not involve any moral hazard problems.

financing (syndication) is indeed more related to round financing than to milestone financing.

The empirical prediction for further testing the model is that later-stage syndication has a direct and positive relation with external risk while it is unrelated to internal risk. In Kaplan and Stromberg (2004), the authors empirically distinguish the external and the internal risk in the venture capital project and then study their relations to the entrepreneur's compensation and the venture capitalist's control. Using a similar methodology, the model of this paper can be tested by studying the relationship between the likelihood of later-stage syndication and the degree of external risk and internal risk in venture capital project.

In the literature of venture capital, there are many papers that study stage financing but only a few look at the negative side of stage financing. In particular, very few papers examine the inefficiency of staging due to its disincentive effect and offer the insight that syndication can be a mechanism to mitigate this effect. A close study is Cornelli and Yosha (2003), particularly for the model setup. The authors model the negative side of stage financing resulting from 'window dressing' by the entrepreneur (i.e. the entrepreneur may react to the prospect of early liquidation in stage financing with an attempt to manipulate available information). Another close work is Fluck, Garrison and Myers (2005), in which the authors also argue that stage financing should be open to syndication at a later stage in order to incentivize the entrepreneur. But both the mechanism of the model and the methodology of the paper are different in their paper and my paper.

In Fluck, Garrison and Myers (2005), the role of later-stage syndication is to reduce the initial venture capitalist's ownership and thus alleviate the holding-up from the venture capitalist. In contrast, in this paper, later-stage syndication is to introduce the information asymmetry into the firm and thus the venture capitalist can realize her commitment. It is important to emphasize that the source of inefficiency in my paper - the lack of commitment - is different with the holding-up problem in Fluck, Garrison and Myers (2005). The holding-up problem means the venture capitalist may not continue a positive-NPV project as she wants to demand a higher payoff from the entrepreneur through her bargaining power. This is never the case in my model. The venture capitalist always continues a positive-NPV project. The problem is rather that she cannot commit to continue a negative-NPV project. In fact, in my setting, the venture capitalist obtains the entire monetary payoff of the project. She cannot demand more from the entrepreneur who is penniless and has no monetary payoff at all. Hence the venture capitalist has no room and no reason to hold up.[7] Moreover, that paper adopts a new methodology of computing finance, while my model uses conventional analysis. Interestingly, however, as Fluck, Garrison and Myers (2005) and my paper are in the same direction and draw a similar conclusion: later-stage syndication has an incentive role, the divergence of the specific mechanism to reach the result (i.e. holding-up, or lack of commitment or both) is open to future empirical studies.

A small literature provides other explanations for the use of syndication in venture capital situations. Lerner (1994) suggests the selection hypothesis as a rationale for venture capital syndication. Wilson (1986) attributes syndication to venture capitalists' risk aversion. Cassamatta and Haritchabalet (2004), Manigart et al. (2005) and Bygrave (1987) argue syndication helps aggregate the different information and/or expertise of the venture capital investors. However, the concern of project selection, aggregation of information or risk sharing should be most important in early rather than in later-stage investments as the early stage involves greater information asymmetry and uncertainty. It is not clear why the later-stage venture capital investments rather than the early-stage are more likely to be syndicated.

Furthermore, people may argue that later stage syndication financing may be due to the VC being risk averse and later stage financing tranches being typically larger. By this argument, however, the buyout deals (alongside with venture capital deals which are often made by the same or similar private equity funds) should involve syndication even more often because buyout deals are usually much bigger than VC deals. Yet this predication is not supported by the available evidence that buyout deals are much less frequent to involve syndication than VC deals (Fenn, Liang and Prowse (1997)). Also, if the risk-aversion at the later stage is the only reason, then later-stage syndication should be equally likely to occur both in round financing and in milestone financing. But this predication is again not consistent with the empirical finding that syndication is more related to round financing than to milestone financing (Bienz and Hirsch (2005)). At the same time, however, I cannot deny the multiple motivations for the use of syndication in reality. The theory in this paper, which highlights the role of later-stage syndication, can be seen as

[7]One clear sign of the distinction of two papers is that the information asymmetry between the lead venture capitalist and the partner venture capitalists in Fluck, Garrison and Myers (2005) has a negative impact on the project value while in my paper such information asymmetry is necessary to achieve efficiency.

complementary to the existing rationales for syndication.

From the theoretical perspective, this paper first shows outside financing under information asymmetry can work as a commitment mechanism. While several papers in the corporate control literature also study the multiple creditors' role in the balance between the ex-ante and ex-post efficiency, the specific mechanism in this paper to realize the ex-ante commitment - due to ex-post information asymmetry - is completely new and different. In Bolton and Scharfstein (1996), the presence of multiple creditors inducing the inefficient renegotiation is a mechanism to deter the strategic default, which trades off against the costs of realizing a low liquidation value in case of liquidity default. Dewatripont and Tirole (1994) show that switching control rights across heterogeneous claimants is a commitment devise. Laux (2001) argues that reducing the headquarters' claim on the project's cash flow by carrying out the project within a subsidiary and using partial external financing in the subsidiary can enable the headquarters to commit to monitor the quality of the project prior to marking a continuation investment. Clearly, all the commitment mechanisms discussed above are unrelated to asymmetric information. Of course, I also use the insight to study venture capital financing and provide a new explanation for one stylized fact - the combined use of stage financing and syndication.

The remainder of the paper is organized as follows. Section I introduces the model setup and the benchmark model where only pure stage financing is used and hence there is a tension between the entrepreneur's effort and lack of commitment by the venture capitalist. In section II, I show how the combined use of syndication with stage financing can be a mechanism to resolve this tension. In section III, I discuss the robustness of the model. In section IV, I discuss the related issues of the paper and provide empirical predications of the model. Section V concludes.

I. The model

I.1. The setup

The model is cast in a simple framework of contract incompleteness and risk neutrality. I use the setup similar to Cornelli and Yosha (2002). There are three dates in the model - T_0, T_1 and T_2.

The net risk-free interest rate in the economy is normalized to 0 while the subjective time discount factors are assumed to be 1.

Consider a venture project which requires two rounds of investment at T_0 and T_1 respectively. The first round of investment is I_1. At T_0 the entrepreneur needs to exert his effort e (where $e \in [0,1]$) to boost the venture's prospect. Specifically, the effort influences the probability of the realization of two states ('Success' and 'Failure') of the project at T_1. The probability for 'Success' is e (equal to effort) while the probability of 'Failure' is $1-e$.[8] In 'Failure' state, the project realizes 0 final payoff at T_2 with probability 1. In 'Success' state, conditional on that the second round of investment I_2 is made, the project realizes the final payoff $\tilde{x}$ at T_2. The $\tilde{x}$ is a random variable with density as $f(x|\theta)$, where θ is the signal that the entrepreneur and the venture capitalist (VC) but no third party receive at T_1. The density $f(x|\theta)$ is positive in the support $\{0, \bar{X}\}$ and satisfies First Stochastic Dominance with respect to θ, where $\bar{X} > 0$.[9] The $\tilde{\theta}$ has density of $g(\theta)$ in the support $[0,1]$.

Two comments about θ are in order. Firstly, the signal θ is not *contractable* since it is not observable by a third party. Secondly, the $\tilde{\theta}$'s distribution $g(\theta)$ is exogenous, which means that, conditional on 'Success' state, the realization of θ at T_1 is independent of the entrepreneur's *ex-ante* effort. I use this setup to capture the feature that the venture capital project's final payoff not only depends on the entrepreneur's effort but also is exposed to some external risk characterized by θ. Kaplan and Strombeg (2004) define external risks as risks that are equally uncertain for VC and entrepreneur. In my setup, both parties are equally uncertain about the realization of θ. Examples of external risk are the extent of future demand for an undeveloped product, the response of competitors upon the product's introduction, and the receptivity of financial markets when investors try to sell the company or bring it public.[10]

[8] Whether the states are contractable is not crucial to the result. For simplicity, I assume that the states are observable by the entrepreneur and the venture capitalist but not by any third party. That is, the states are uncontractable.

[9] Specifically, the expression of density is $f(x|\theta) = \begin{cases} q(\theta) & x=\bar{X} \\ 1-q(\theta) & x=0 \end{cases}$ in the support $\{0, \bar{X}\}$, where $0 < q(\theta) < 1$ and $q'(\theta) > 0$.

[10] In fact, in my setup, the state ('Success' and 'Failure') is the internal risk. Kaplan and Stromberg (2004) define internal risk as uncertainties about which the entrepreneur is better informed than the VC. It relates to asymmetric information and is the main cause of agency problem. Indeed, in my setup, the entrepreneur is better informed of

Obviously, from the setup, it is not optimal for VC to pay all the capital necessary to finance the project up front. The staging of capital infusions is better.[11] Further, since the states ('Success' and 'Failure') and θ are uncontracable, stage financing can only be in form of round financing rather than milestone financing.[12]

At T_1, the VC needs to make the *refinancing* decision, which is equivalent to the *liquidation/continuation* decision.[13] If the VC denies infusion of the second round of financing, the project has to be liquidated. In the case of liquidation, the project realizes the liquidation value L at T_1 in either state. For simplicity and without loss of generality, I normalize L to 0. If the VC agrees to make the second round of investment I_2, the project is continued. As I will show, in 'Failure' state it is optimal for the VC to deny the refinancing. The key decision for the VC at T_1 is whether she should continue the project in 'Success' state after she receives the signal θ. Suppose the VC uses a simple 'switch' strategy and sets the threshold to θ^* (i.e. she continues the project if and only if $\theta \geq \theta^*$). Then the probability of the project's continuation at T_1 conditional on 'Success' state is $p = \int_{\theta=\theta^*}^{\theta=1} g(\theta)d\theta$. Hence the *ex-ante* probability of the project's continuation is $e \cdot p$. To rule out trivial cases, I assume $E(\tilde{x}|\theta = 0) < I_2 < E(\tilde{x}|\theta = 1)$. Without loss of generality, I also assume $\int_{\theta=0}^{\theta=1} E(\tilde{x}|\theta) \cdot g(\theta)d\theta \leq I_2$.[14]

the realization of the states ('Success' or 'Failure') than the VC. In fact, the entrepreneur can affect the realization of the states (by his own effort) to some extent while the VC cannot observe the entrepreneur's effort and hence she is totally uncertain about the realization of the states.

[11] If the VC pays all the capital up front, the entrepreneur will always continue the project at T_1 and the VC loses the option of efficient controlling continuation/liquidation. As Admati and Pfleiderer (1994) show, entrepreneur will almost never quit a failing project himself as long as others are providing capital.

[12] Round financing means that every new tranche is negotiated separately when the venture needs further funding; milestone financing requires that exact contingencies that the firm has to achieve to obtain new funds are fixed in the initial contract (Bienz and Hirsch (2005)). In fact, even if the states ('Success' and 'Failure') are contractable, it is still not optimal for VC to contract the refinancing decision contingent on the states. It is too costly for VC to continue the project with all realized θs in 'Success' state. This setup catches the feature of some young and immature firms where uncertainty is too high to provide firms with proper milestones.

[13] The outsider is uninformed of the quality of the project characterized by the states ('Success' and 'Failure') and the θ. Hence the entrepreneur cannot raise the funding from a new investor if the old VC denies the funding. The project has to be liquidated.

[14] In fact, this assumption is not a necessary condition to derive the result of the paper. The only purpose for using this assumption is to rule out some uninteresting cases. The weaker assumption $E(\tilde{x}|\theta = 0) < I_2$ is sufficient to derive the result. It will be clear later on that the uninteresting case is $\theta^*_{SB} = 0$. Please refer to footnote 22.

Figure 1 describes the timeline.

(Insert Figure 1 here)

I assume the entrepreneur derives his utility from the private benefit of running the firm in the second period.[15] Specifically, the entrepreneur's *ex-ante* utility function is assumed to be $U(e) = B \times (e \times p) - \Psi(e)$, where B is his private benefit to run the firm in the second period.[16] The term $e \times p$ is his probability that the VC will not liquidate the firm at T_1 while the term $\Psi(e)$ is the entrepreneur's disutility from exerting effort, which satisfies the standard conditions $\Psi'(e) > 0$ and $\Psi''(e) > 0$. Moreover, $\Psi(0) = 0, \Psi'(0) = 0$ and $\Psi(1) = +\infty$. Here I abstract from the entrepreneur's monetary compensation by normalizing it to 0 at T_1 and T_2. Actually I will show that no compensation scheme can solve the *commitment problem*, hence compensation is insufficient in the sense that it cannot eliminate the inefficiency I am considering. At this stage, we can think of the private benefit B as being so high to make any monetary payoff negligible, hence the entrepreneur's monetary payoff doesn't enter his utility function. Hereafter I normalize B to unity (i.e. $B \equiv 1$). By the first order condition: $U'(e) = p - \Psi'(e) = 0$, e is an increasing function with respect to p (as $e = \Psi'^{-1}(p)$ is increasing). That is, the higher the probability that the VC will continue the project, the higher the entrepreneur's effort. Clearly, the highest effort that the VC can incentivize the entrepreneur to make is $\bar{e} = \Psi'^{-1}(1)$ considering $p \leq 1$.

I assume that VC only cares about her monetary payoff. Her utility is the net monetary payoff of her investment.

I.2. The benchmark: the venture project is purely stage financed

As a benchmark, in this section I assume that the venture project is purely stage financed. That is, the VC solely pays the investments required to the project. If this is the case, the VC's utility is equal to the NPV of the project. Her utility as a function of θ^* can be expressed by

[15] Naturally entrepreneur has high private benefits if his new product is commercialized and/or his firm is brought to the IPO. The venture capital project is in fact his 'baby'.

[16] I assume that the VC cannot run the firm without the entrepreneur's participation (maybe due to the entrepreneur's inalienable human capital).

$$V(\theta^*) = \overbrace{-I_1}^{\substack{\text{The inital} \\ \text{investment} \\ \text{at } T_0}} + e \overbrace{\int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - I_2] \cdot g(\theta) d\theta}^{\substack{\text{The expected NPV} \\ \text{of the project} \\ \text{in the second period}}}$$

Given I_1 and I_2, the VC's utility function depends on the entrepreneur's *ex-ante* effort e and the VC's *ex-post* control θ^*. From the ex-ante perspective, in order to give entrepreneur the highest incentive to exert effort, the VC's control decision should be $\theta^*_{et} = 0$,[17] where θ^*_{et} denotes the VC's decision to achieve highest *ex-ante* effort. In contrast, after the entrepreneur's effort has been sunk (i.e. e is given), the VC's *ex-post* efficient control should be $\theta^*_{ep} = \min\{\theta | \ E(\tilde{x}|\theta) \geq I_2\}$.[18] That is, *ex-post*, the VC should continue the project if and only if the project's expected payoff at T_2 is higher than the cost of continuing - the second round of investment I_2.[19]

By assumption $E(\tilde{x}|\theta = 0) < I_2$, I have $\theta^*_{et} < \theta^*_{ep}$. The fact that θ^*_{et} is not equal to θ^*_{ep} demonstrates that the VC cannot achieve the *ex-ante* highest incentive and *ex-post* efficient control *simultaneously*.[20] Further, as θ^* moves from θ^*_{et} to θ^*_{ep} in the interval $[\theta^*_{et}, \theta^*_{ep}]$, the *ex-ante incentive* efficiency (the e term) decreases while the *ex-post control* efficiency (the term $\int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - I_2] \cdot g(\theta)d\theta$) increases. The highest overall efficiency should be the result of the trade-off between these two efficiencies. Naturally, in the world where θ is contractable, such a trade-off is feasible.

[17] This is the result of the optimization problem

$$\underset{\theta^*}{Max} \ e$$
$$\equiv \underset{\theta^*}{Max} \ \Psi'^{-1}\left(\int_{\theta=\theta^*}^{\theta=1} g(\theta)d\theta\right)$$

[18] This is the result of the optimization problem

$$\underset{\theta^*}{Max} \ V(\theta^*)$$
$$\equiv -I_1 + e \int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - I_2] \cdot g(\theta)d\theta$$

where e is a constant.

[19] Also, here I can justify that the 'liquidation' is the VC's optimal strategy in 'Failure' state from the perspective of both ex-ante and ex-post. Ex-post, the investment I_2 at T_1 is higher than cash flow 0 at T_2. It is not optimal to continue. Ex-ante, the VC must threaten to liquidate the project in order to incentivize the entrepreneur to exert effort.

[20] Here control refers to real control rather than formal control. Aghion and Tirole (1997) distinguish the formal and real control.

If θ^* is contractable, the VC's problem is to find an optimal θ^* to be contracted to maximize her utility. Program 1 solves such a problem:

Program 1 ($P1$):

$$\underset{\theta^*}{Max} V(\theta^*)$$

$$\equiv \underset{\theta^*}{Max} \quad -I_1 + e \int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - I_2] \cdot g(\theta) d\theta \tag{1}$$

$$\equiv \underset{\theta^*}{Max} \quad e \int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - I_2] \cdot g(\theta) d\theta \tag{2}$$

$$s.t. \quad \int_{\theta=\theta^*}^{\theta=1} g(\theta) d\theta = \Psi'(e) \qquad \text{(IC of the entrepreneur)} \tag{3}$$

I denote the optimal θ^* in the above program as θ^*_{SB} and the utility V at the optimum as V_{SB}.[21]

I can prove that $\theta^*_{SB} < \theta^*_{ep}$. In fact, if we evaluate the first-order derivative of the VC's utility function at θ^*_{ep}, we obtain

$$\frac{\partial V}{\partial \theta^*}|_{\theta^*=\theta^*_{ep}} = \underbrace{\frac{\partial e}{\partial \theta^*}}_{<0} \underbrace{\int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - I_2] \cdot g(\theta) d\theta}_{>0} - \underbrace{[E(\tilde{x}|\theta^*) - I_2] \cdot g(\theta^*) \cdot e}_{=0}$$

$$< 0,$$

which means that there is scope to decrease θ^*_{ep} to increase the utility, that is,

$$\theta^*_{SB} < \theta^*_{ep} \text{ and } V(\theta^*_{ep}) < V_{SB}.\text{[22]} \tag{4}$$

I define the outcome vector (θ^*_{SB}, V_{SB}) determined by Program 1 as the Second-best.[23] Formally,

[21] I assume that V_{SB} is positive. That is, the VC's ex-ante participation constraint is satisfied.

[22] Similarly, by the assumption $\int_{\theta=0}^{\theta=1} E(\tilde{x}|\theta) \cdot g(\theta) d\theta \leq I_2$, I can also show that $\theta^*_{SB} > 0$. In fact, $\frac{\partial V}{\partial \theta^*}|_{\theta^*=0} = \underbrace{\frac{\partial e}{\partial \theta^*}}_{<0} \underbrace{\int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - I_2] \cdot g(\theta) d\theta}_{\leq 0} - \underbrace{[E(\tilde{x}|\theta^*) - I_2] \cdot g(\theta^*) \cdot e}_{<0} > 0.$

[23] "Second-best" is in the sense that there is still the agency problem of unobservable effort of the entrepreneur.

Definition 1 *(Second-best): If there is an equilibrium in which the outcome vector* (θ^*, V) *is identical to* (θ^*_{SB}, V_{SB}), *then we say that this equilibrium achieves the second-best.*

Now let us consider the case when the θ is uncontractable, which is the assumption of my setup. In fact, as the entrepreneur moves first (exerting his effort), the VC moves later (choosing her refinancing decision), and the VC cannot *commit* not to choose her ex-post efficient level θ^*_{ep} after the entrepreneur's effort has been sunk, the unique equilibrium for this sequential game is as follows.

Theorem 1 *(Pure stage financing Equilibrium) When the venture project is purely stage financed, there is a unique SPNE (Subgame Perfect Nash Equilibrium) of the game in which the strategy profile is* $(\sigma_E, \sigma_V) = (e_{ep}, \theta^*_{ep})$, *where* σ_E *is the entrepreneur's strategy,* σ_V *is the VC's strategy, and* $e_{ep} = \Psi'^{-1}(\int_{\theta=\theta^*_{ep}}^{\theta=1} g(\theta)d\theta))$. *In such an equilibrium, ex-post efficient control is achieved while ex-ante efficient incentive is not.*

From (4), we know that the VC's utility under ex-post efficiency is lower than that under the second-best. Moreover, since the entrepreneur exerts less effort under ex-post efficiency than under the second-best, the entrepreneur's utility decreases as well.[24] Therefore, the second-best strictly Pareto dominates the pure stage financing equilibrium.

I summarize the above results in Theorem 2.

Theorem 2 *The equilibrium when the project is purely stage financed is strictly sub-optimal relative to the second-best in terms of maximizing the VC's utility. Moreover, from the viewpoint of social welfare, the second-best strictly Pareto dominates the pure stage financing equilibrium.*

Proof: see the Appendix.

The fact that the pure stage financing equilibrium is strictly sub-optimal relative to the second-best highlights the necessity of VC's commitment to continuing the project more often than is

[24] I provide the formal proof of this assertion in the appendix.

efficient *ex-post*, which can boost *ex-ante* incentive. However, in the θ-uncontractable world, the VC lacks the mechanism to commit to such a concession, which in turn induces the entrepreneur to exert effort less than the second-best level. This, in the end, reduces the VC's welfare. In the next section, I will show that syndication can actually form a mechanism that enables the VC's commitment making the second-best implementable.

II. The implementation: the second-best is implementable via contract design

In this section, I show that syndication can overcome the commitment issue. Hereafter, I suppose that there is a partner VC (besides the lead VC) participating in the second round of financing, who is uninformed of the signal θ. In order to highlight the role of later-stage syndication, I assume that the first round of investment is still solely financed by the lead VC. I show that after introducing an uninformed third party (i.e. the partner VC) into the firm, the lead VC automatically continues the project more often. The second-best is implementable. The intuition of the mechanism is in the same spirit as Myers and Majluf (1984), that is, external financing (i.e. syndication) under asymmetric information can lead to the unprofitable project being (re)financed and hence continued.

II.1. The financial contract

Before I provide a formal proof of the implementation, I need to discuss the financial contract regarding the venture capital-backed firm we are considering. Specifically, I define financial contract C', whose terms are summarized in Figure 2. The formal definition of C' is provided in the footnote.[25]

[25]

Definition 2 *The financial contract of the firm is a vector* $C := (\{(\{(CF_t^j, CR_t^j)\}_{t=0}^{2})\}_{j=1}^{J})$, *where* J *is the number of claimants.* $CF_t^j (\in R)$ *is the cash flow for claimant* j *at time* t*; it can be positive, zero or negative.* CR_t^j $(\subset SD_t)$ *is the decision right endowed to claimant* j *at time* t *where* SD_t *is the set of all decisions made for the firm at time* t*.*

Definition 3 *We define* $\{C'\}$, *which is a contract subspace of* $\{C\}$ *such that*

(Insert Figure 2 here)

Figure 2 describes the cash flow and decision rights allocation under the contract C'. The basic specification of the contract C' can be expressed as follows. There are two security holders: the partner VC who is uninformed of the signal θ and the lead VC. At T_0, the lead VC contributes I_1 toward the initial investment. At T_1 it is up to the lead VC to decide whether to refinance the project.[26] If not refinancing, the partner VC doesn't participate. If refinancing, the lead VC needs to pay $I_2 - F$ toward part of the second round of investment, while the partner VC is responsible for the remaining part: F. If the project is refinanced, at T_2 the lead VC receives the state-contingent claim $\tilde{x} - s(\tilde{x})$ while the partner VC gets the remaining payoff $s(\tilde{x})$. Actually, the only unspecified clauses in the contract C' are F and $s(\tilde{x})$. Hence, hereafter I use the vector $(F, s(\tilde{x}))$ to denote the contract in space $\{C'\}$. I also assume that the partner VC is risk-neutral and he joins the financing at competitive terms.[27]

Under the financial contract $(F, s(\tilde{x}))$, the lead VC's utility function becomes

---

$J = 2$

and

$C' = (((CF_0^E, CR_0^E),(CF_1^E, CR_1^E),(CF_2^E, CR_2^E)), ((CF_0^O, CR_0^O),(CF_1^O, CR_1^O),(CF_2^O, CR_2^O)))$

where $E = Lead\ VC$, $O = Partner\ VC$;

$CF_0^E = -I_1$, $CF_0^O = 0$; $CR_0^E = nothing$, $CR_0^O = nothing$;

$$CF_1^E = \begin{cases} -(I_2 - F) & \text{if firm is refinanced} \\ 0 & \text{if firm is not refinanced} \end{cases}, CF_1^O = \begin{cases} -F & \text{if firm is refinanced} \\ 0 & \text{if firm is not refinanced} \end{cases};$$

$CR_1^E = refinance\ or\ not$, $CR_1^O = nothing$;

$CF_2^E = \tilde{x} - s(\tilde{x})$, $CF_2^O = s(\tilde{x})$; $CR_2^E = nothing$, $CR_2^O = nothing$;

Both $s(\tilde{x})$ and $\tilde{x} - s(\tilde{x})$ are non-negative and non-decreasing with respect to $\tilde{x}$ (Innes (1990)). (5)

[26] Considering the information structure in our setup where at T_1 only the lead VC and entrepreneur can observe the signal θ, it is natural to limit the contract space to the one that still gives the refinancing decision rights to the lead VC rather than the partner VC. It is not optimal to give the decision rights to entrepreneur, who always wants to continue.

[27] Under the relaxed assumption that the partner VC demands positive rent for financing, the main result of the model does not change.

$$V(\theta^*) = \overbrace{-I_1}^{\substack{\text{The lead VC's} \\ \text{initial investment} \\ \text{at T}_0}} + e \overbrace{\int_{\theta=\theta^*}^{\theta=1} E\{[\tilde{x} - s(\tilde{x})] - (I_2 - F)|\theta\} \cdot g(\theta)d\theta}^{\substack{\text{The expected NPV} \\ \text{for the lead VC} \\ \text{in the second period}}} \tag{6}$$

Ex-post, the lead VC continues the project if and only if her expected payoff at T_2 of continuing is higher than the cost of continuing, that is,

$\theta^* = \min\{\theta| \ E[\tilde{x} - s(\tilde{x})|\theta] \geq I_2 - F\}$.

As for the partner VC who is **uninformed** of θ, since his reserve utility is zero, his participation condition is:

$$\int_{\theta=\theta^*}^{\theta=1} (E[s(\tilde{x})|\theta] - F) \cdot g(\theta)d\theta = 0. \text{ [28]} \tag{7}$$

As for the entrepreneur, his decision is still governed by his (IC) condition (3).

II.2. Implementing the second-best with the financial contract

The lead VC decides the financial structure (that is, chooses the financial contract $(F, s(\tilde{x}))$) at T_0 when the project starts. Such a decision is made *before* the entrepreneur's decision to exert effort. Figure (3) describes the new timeline.

(Insert Figure 3 here)

As the partner VC breaks even and receives zero surplus, the lead VC obtains the same surplus and utility under the financial contract $(F, s(\tilde{x}))$ as at the second best if she chooses θ^* as θ^*_{SB}. Formally,

Lemma 1 *Under the financial contract* $(F, s(\tilde{x}))$*, if* θ^*_{SB} *is implemented in equilibrium, then* V_{SB} *will be automatically implemented.*

[28] The partner VC's participation constraint is binding in the case of this paper.

Proof: If I add the LHS of (7) to the RHS (6), I obtain

$$V(\theta^*) = -I_1 + e \int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - I_2] \cdot g(\theta)d\theta \tag{8}$$

which is identical with the objective function (1) in $(P1)$. Therefore, if θ^*_{SB} is implemented (hence e under the second-best is implemented), V_{SB} will be implemented. Q.E.D.

From Lemma 1, I can conclude that in order to implement the second-best we only need to implement θ^* at θ^*_{SB}. Further, from the analysis in the last subsection, we know that θ^* under the financial contract $(F, s(\tilde{x}))$ is determined by the following joint equations

$$\begin{cases} \theta^* = \min\{\theta | E[\tilde{x} - s(\tilde{x})|\theta] \geq I_2 - F\} & \text{(the lead VC's rational choice)} \quad (9) \\ \int_{\theta=\theta^*}^{\theta=1} (E[s(\tilde{x})|\theta] - F) \cdot g(\theta)d\theta = 0 & \text{(IR of the partner VC)} \quad (10) \end{cases}$$

Note that $\tilde{x}$ can only be one of two values: 0 and $\bar{X}$. By limited liability of the lead VC, we have $s(0) = 0$. I also denote $s(\bar{X}) = K$, where K is the payoff for the partner VC at date 2 contingent on that the project's final payoff is $\bar{X}$. Taking I_2 and F as parameters, there are only two unknown variables θ^* and K in the joint equations (10) and (11) while we also have two equations. Hence, the equation system is solvable. Given I_2, the $s(\tilde{x})$ (i.e. equivalent to K) and θ^* are both uniquely determined by F. I denote the map between F and θ^* as $\theta^* = \theta^*(F)$. Now the implementation problem of the second-best is converted to the problem whether I can find an F such that $\theta^*(F) = \theta^*_{SB}$.

I discuss two properties of $\theta^*(F)$ first.

Lemma 2 *If $F > 0$, θ^* is downward biased (i.e. $\theta^*(F) < \theta^*_{ep}$).*

I provide the mathematical proof first. In order to satisfy the participation condition (10) of the partner VC, K must be strictly positive. That is, $s(x)$ is a strictly increasing function in $\{0, \bar{X}\}$. Hence $s(x)$ becomes an information sensitive security.[29] A higher θ will lead to higher $E[s(\tilde{x})|\theta]$. From (10), we know that the new VC claims F on average for all θ in $[\theta^*(F), 1]$. Therefore, the claim for the lowest signal $\theta^*(F)$ must be lower than F, that is, $E[s(\tilde{x})|\theta^*(F)] < F$. While we have

[29] The expected value of $s(\tilde{x})$ will change as the signal θ changes.

$E[\tilde{x} - s(\tilde{x})|\theta^*(F)] = I_2 - F$ by (9), $E[\tilde{x}|\theta^*(F)]$, which equals $E[s(\tilde{x})|\theta^*(F)] + E[\tilde{x} - s(\tilde{x})|\theta^*(F)]$, must be lower than I_2. Combining the above result with $E(\tilde{x}|\theta^*_{ep}) = I_2$, the relation $\theta^*(F) < \theta^*_{ep}$ follows.

The intuition for the lead VC's decision bias under syndication is direct when explained in the framework of Myers and Majluf (1984). In fact, after the initial date T_0's investment I_1 has been sunk, the lead VC's (forward-looking) refinancing decision at T_1 is a one-period investment decision, which is essentially the one in Myers and Majluf (1984). That is, the lead VC is making a decision whether to invest a project with the investment cost as I_2 and payoff as $\tilde{x}$ at the next date. This financing and investment decision is made under *asymmetric information* as the lead investor but not an outsider knows the project's quality (or type) (which is characterized and indexed by the continuous real number θ). By Myers and Majluf (1984), if the project is fully *internally* financed, the efficient separating equilibrium is achieved, i.e. the project is financed and invested if and only if it is profitable, that is, if and only if $E[\tilde{x}|\theta] \geq I_2$. This is exactly the equilibrium of our model when the project is purely stage financed without syndication. However, if the lead investor is 'financially constrained' and she has to raise F amount of *external finance* from an uninformed outsider, from Myers and Majluf (1984) we immediately conclude that inefficient pooling is unavoidable (Note: unavoidable because the project type θ in my setup is continuous, which is a bit different from Myers and Majluf (1984)'s setting where project type is discrete ('Good' or 'Bad')). That is, some unprofitable bad types of project (with a low θ), which are 'subsidized' by the good types (with a high θ), will necessarily be financed. This inefficient pooling is the fundamental reason for the lead VC's decision bias when syndication is used in our model.

The two key messages from Myers and Majluf (1984) are:

Message 1: If the firm uses external finance, the bad type of firm is possible to be pooled with the good type and hence be financed.

Applying this message to the context of our model and also considering that the project type θ in our setup is continuous, the intuition of Lemma 2 is direct.

It is worth noting that the result in Lemma 2 (and thus the robustness of the model) doesn't depend on the specific assumption of the binary payoff structure of the paper – the project either pays zero or $\bar{X}$. Suppose for instance that project returns follow some continuous distribution function. Under the new assumption, as long as $s(x)$ satisfies (5) of Innes (1990)'s condition (hence $s(x)$ is an information sensitive security $\frac{\partial E[s(\tilde{x})|\theta]}{\partial \theta} > 0$) but no matter whether $s(x)$ is convex or concave, by Myers and Majluf (1984) the pooling equilibrium is unavoidable, that is, θ^* goes down. The mechanism here is different with the asset substitution problem (i.e. equity-like claim for VC will induce her to continue excessively while debt-like claim leads to the opposite effect).

Message 2: The more external finance the firm uses, there is a higher possibility of inefficient pooling (i.e. the bad type of firm is more likely to be financed).

The counterpart to this message is the following Lemma.

Lemma 3 *The lead VC's decision bias under syndication is continuous and increasing with respect to F (i.e. $\theta^*(F)$ is decreasing in F).*

Proof: See the Appendix.

Now I am ready to present that the second-best can be implemented by the contract $(F, s(x))$.

Theorem 3 *There exists a financial contract in space {(F, s(x))} that can implement the second-best. That is, there exists an F lying in the interval $(0, I_2)$ such that $\theta^*(F) = \theta^*_{SB}$.*

Proof: See the appendix.

I denote this contract that implements the second-best as $(F^*,\ s^*(x))$, where
$s^*(x) = \begin{cases} 0 & \text{when } x = 0 \\ K^* & \text{when } x = \bar{X} \end{cases}$ and K^* is endogenously determined by (10).

(Insert Figure 4 here)

I present the formal proof of Theorem 3 in the Appendix. Figure 4 shows the basic intuition. In Figure 4, if the lead VC uses 0 syndicate financing (i.e. F is 0), she chooses θ^* as θ^*_{ep}. As syndicate financing F increases, θ^* falls. In the extreme case, if syndicate financing F equals I_2, θ^* is 0.[30] Hence, there is an F^* between 0 and I_2 which can implement θ^*_{SB}.

[30] A more rigorous analysis for the extreme case is provided in the Appendix.

Theorems 3 implies the contract terms of syndication. That is, the partner VC pays F^* amount of capital participating in syndication and obtain $\frac{K^*}{\bar{X}}$ proportion of the firm's total shares as payoff. Moreover, the partner VC mainly has cash flow rights but few control rights (e.g. continuation /liquidation decision rights). This arrangement of syndicate contract seems quite consistent with reality.

So far I have presented that syndicate financing can work as a mechanism to overcome the commitment problem of pure stage financing. That is, the combined use of later-stage syndication with stage financing can maximize the firm value.

III. Robustness issues

III.1. Renegotiation is impossible

I consider renegotiation between the lead VC and the entrepreneur and between the lead VC and the partner VC in order.

Between the lead VC and the entrepreneur

As the entrepreneur derives a private benefit from continuing the project, there may exist some θ (below θ^*_{SB}) at which continuation is socially optimal (i.e. the private benefit plus the monetary payoff) while liquidation is the equilibrium in the second-best. In such cases, renegotiation is mutually beneficial to both the lead VC and the entrepreneur ex-post. However, because the entrepreneur is penniless and obtains zero monetary compensation from the project, he does not have any financial resources to bribe the lead VC into continuation incurring. Therefore, renegotiation in this case is impossible.

Between the lead VC and the partner VC

Renegotiation between the lead VC and the partner VC is impossible due to the information asymmetry. In fact, when $\theta \in [\theta^*_{SB}, \theta^*_{ep}]$ the lead VC inefficiently continues the unprofitable project in the second-best. There is scope for the lead VC and the partner VC to engage in mutually beneficial renegotiation *ex-post* at T_1. However, due to asymmetric information between the two parties (i.e. the partner VC cannot observe θ), the only possibility for mutually beneficial renegotiation is that the lead VC initializes the proposal for a new contract after she observes $\theta \in [\theta^*_{SB}, \theta^*_{ep}]$.[31] The new contract provides not to refinance (and liquidate) the project but the partner VC needs to pay some money to compensate the lead VC.[32] But the lead VC can provide the same proposal when $\theta < \theta^*_{SB}$ in which she does not decide to refinance the project anyway even under the original contract and thus the new contract is only beneficial to the lead VC while making the partner VC worse off. Therefore, the partner VC will not 'trust' the lead VC. Hence, the renegotiation in this case will not happen either. The second-best equilibrium is sustained.

III.2. Monetary compensation for the entrepreneur is insufficient

In this subsection I am going to prove that the monetary compensation scheme for the entrepreneur is insufficient because it cannot solve the commitment problem I discuss above. This is the reason why I could abstract from monetary compensation by normalizing it to zero so far.

I provide the intuition first. Suppose the entrepreneur cares about the monetary payoff as well as the private benefit. His ex-ante effort depends on his expectation on these two kinds of payoffs. Thus, there are also two ways for the lead VC to incentivize the entrepreneur to exert effort: pay the entrepreneur a monetary compensation or give the entrepreneur her commitment to continue the project. The latter concerns the second type of payoff — the private benefit. Note that both of the above two incentives are costly to the lead VC. It is obvious that monetary compensation is costly. The commitment is costly because some unprofitable project will be continued under the commitment. In order to incentivize the entrepreneur to exert a certain level of effort, I am arguing that the optimal compensation policy should be a mix of monetary compensation and commitment. It is never optimal for the lead VC to use just one incentive. In particular, monetary compensation alone is too costly relative to a mix of monetary compensation and commitment to achieve a certain level of effort. That is, the commitment is always necessary for minimizing the lead VC's cost and maximizing her wealth. In order to highlight and concentrate on the effect of commitment instead of monetary compensation on effort, I have disregarded the monetary compensation and assume the entrepreneur does not care about money or that the monetary payoff is negligible compared to the private benefit.

[31] In fact, this is a signaling game.

[32] Without loss of generality, I assume that the lead VC has full bargain power.

Now let us move to the mathematical proof. I consider all possible monetary compensation schemes for the entrepreneur. Note that my assumption is that the 'Success' and the 'Failure' states are uncontractable. The only contractable variable is the 'continuation' and 'liquidation' decision. Therefore, the available compensation schemes for the entrepreneur can be expressed in the form of $(n, m(x))$, where n (≥ 0) is a constant salary in case of 'Liquidation' and $m(x)$ is the compensation in case of 'Continuation'. Under such compensation, the entrepreneur's utility can be rewritten as $U(e) = [(1-e) + e(1-p)] \cdot n + e \cdot \int_{\theta=\theta^*}^{\theta=1} \{B + E[m(\bar{x})|\theta]\} \cdot g(\theta)d\theta - \Psi(e)$. Since the project's liquidation value is zero, n must be 0.[33]

When the firm is purely stage financed (i.e. no syndication), under the compensation scheme $(n = 0, m(x))$, the lead VC's utility is

$$V(\theta^*) = -I_1 + e \cdot \int_{\theta=\theta^*}^{\theta=1} \{E[\tilde{x} - m(\tilde{x})|\theta] - I_2\} \cdot g(\theta)d\theta \qquad (12)$$

Ex-post, the lead VC chooses θ^* as $\theta^*_{ep} = \min\{\theta | \ E[\tilde{x} - m(\tilde{x})|\theta] \geq I_2\}$. Again, I can prove that the lead VC's utility $V(\theta^*)$ will increase if θ^* decreases a bit by taking later-stage syndication. In fact,

$$\frac{\partial V}{\partial \theta^*}|_{\theta^*=\theta^*_{ep}} = \underbrace{\frac{\partial e}{\partial \theta^*}}_{<0} \underbrace{\int_{\theta=\theta^*}^{\theta=1} \{E[\tilde{x} - m(\tilde{x})|\theta] - I_2\} \cdot g(\theta)d\theta}_{>0} - \underbrace{\{E[\tilde{x} - m(\tilde{x})|\theta^*] - I_2\} \cdot g(\theta^*) \cdot e}_{=0}$$

$$< 0.$$

Therefore, later-stage syndication is useful and necessary in order to maximize the lead VC's utility.

Nevertheless, when the lead VC pays monetary compensation to the entrepreneur, there is scope for the lead VC and the entrepreneur to renegotiate at T_1 because the entrepreneur is not wealth

[33] Even if the liquidation value is not zero, I can still prove n to be 0. In fact, by the first order condition $U'(e) = 0$,

we have $\int_{\theta=\theta^*}^{\theta=1} \{(B - n) + E[m(\bar{x})|\theta]\} \cdot g(\theta)d\theta = \Psi'(e)$ (IC) (11)

From (11), I obtain that e is a decreasing function of n, that is, the higher the entrepreneur's salary in case of 'liquidation', the lower the effort the entrepreneur exerts. From the perspective of the VC, it is also costly for her to pay the entrepreneur the compensation n. Considering that the VC prefers the entrepreneur to exert high effort, n must therefore be 0 in the optimal compensation. Intuitively, in order to incentivize the entrepreneur to exert effort, it is optimal to the VC to increase the difference in compensation in 'liquidation' and 'continuation'. The highest difference occurs when $n = 0$.

constrained now. Without loss of generality, I assume that the lead VC has all the bargaining power. Without renegotiation, the lead VC chooses θ^* as $\theta^*_{ep} = \min\{\theta|\ E[\tilde{x} - m(\tilde{x})|\theta] \geq I_2\}$. Obviously, the lead VC inefficiently liquidates the project too often. Renegotiation can achieve ex-post efficiency by pushing θ^* down to $\min\{\theta|\ E[\tilde{x}|\theta] \geq I_2\}$. In fact, when $\theta \in [\min\{\theta|\ E[\tilde{x} - m(\tilde{x})|\theta] \geq I_2\}, \min\{\theta|\ E[\tilde{x}|\theta] \geq I_2\}]$, renegotiation results in the project being continued while the lead VC pays zero monetary compensation to the entrepreneur under such continuation. This renegotiation makes both parties better off relative to no renegotiation. The above problem is equivalent to the debt-overhang problem, where 'debt' is $m(\tilde{x})$.

After taking renegotiation into account, the problem is the same as the one I was studying in Section I, where θ^* is also $\theta^*_{ep} = \min\{\theta|\ E[\tilde{x}|\theta] \geq I_2\}$. Clearly, on the basis of monetary compensation $(n, m(x))$, syndication can reduce θ^* further and make θ^* fall below θ^*_{ep} to implement the second-best. Therefore, syndication is necessary even if I take monetary compensation and renegotiation into account.

Finally, I want to point out that the assumption that the 'Success' and the 'Failure' states are uncontractable is not necessary for us to derive the result in this section — monetary compensation is insufficient. I can show that even if the states are contractable, monetary compensation still cannot solve the commitment problem. Syndication, which can realize the commitment, is still necessary. As this argument is not necessary for the paper, I omit its mathematical proof.

IV. Discussion and empirical implications

IV.1. Using later-stage syndication: formal contract Vs implicit enforcement

From the analysis in Section II, using later-stage syndication can be formally contracted. The contract is signed before the entrepreneur's decision to exert effort at T_0. In reality, as with bank syndicated loan contract (Sufi (2007)), the lead VC and the partner VC usually form a syndicate group to contract together with the entrepreneur to finance the entrepreneur's project jointly. The contract specifies the control rights and cash flow rights. Typically the lead VC takes the main responsibility of monitoring the project process (i.e. control) while the partner VC mainly holds cash flow rights. The partner VC can participate in some or all rounds of financing (for example, the partner VC contributes certain proportion of funding at each round). In Section II, in order to highlight the role of later-stage syndication, I assume that the partner VC only participates in the second round of investment. But the model doesn't preclude syndication at an earlier stage. The crucial point is that the later-stage syndication is always *necessary* (otherwise the entrepreneur does not exert sufficient effort).

How popular is the later-stage syndication being formally contracted in advance in reality is largely an empirical question. Since little empirical evidence regarding syndication contracts is available, the answerer to this question requires future empirical work. Nevertheless, if the lead VC, entrepreneur and the outside VC all have a good idea about the structure of the project (e.g. distributions of the signal and the cash flow), later-stage syndication realized by a formal contract should be common in practice.

However, it is important to emphasize that the conclusion in Section II that there exists a (unique) optimal prior syndicate contract is built on some simplifying assumptions, e.g. both the VCs and the entrepreneur precisely know the distributions of the signal and the cash flow. I use these simplifications to provide a benchmark description of a relatively perfect world (as in most theories like the Modigliani-Miller theorems), and thus highlight the main insight of the paper: the later-stage syndication can mitigate the fundamental incentive problem due to external risk. However, these simplified assumptions are not always true in reality. If this is the case, the lead VC's ex-ante commitment to the *exact* terms of syndication by an explicit prior contract is no longer optimal, particularly considering that the ex-ante syndication contract is hard to renegotiate ex-post and renegotiation itself is costly. Therefore, in many situations, more vague commitment may be better. In fact, in the imperfect situation where there is uncertainty about the distributions of signal and cash flow, it is impossible to completely solve the ex-ante incentive problem. However, the commitment to later-stage syndication is still very valuable. As the computation result in Fluck, Garrison and Myers (2005) shows, the tiny ex-post disincentive effect on the ex-ante effort provision can have a significant impact on the overall firm value.

An important implicit mechanism to enforce the lead VC to take later-stage syndication is the partnership covenant. This is also the argument in Fluck, Garrison and Myers (2005). In reality, the covenant in partnership agreements between venture capital firms and their limited partners typically prohibits funds from investing more than a small percentage in any portfolio company and in any round of investment (Sahlman (1990), Fenn, Liang and Prowse (1997)). Such a covenant forms a commitment device that assures that syndication at a later stage is credible, particularly because later-stage investment usually requires a larger investment.

Now the whole logic of the model can be expressed in the following way. That is, although the venture capital fund is not financial constrained at the deal-level (e.g. the capital raised at the time the fund is formed may be enough to cover the required funding for some deals), the covenant forces the deal-level investment to involve some external finance. External financing under asymmetric information, however, will necessarily lead to an inefficient investment decision. In the context of stage financing, it is an inefficient *refinancing and continuation/liquidation* decision because the investment and financing decision as well as the information asymmetry takes place at the intermediate date rather the initial date. (Note: at the initial date, both the insider and the outsider are *equally* uncertain about the quality of the project. But as time goes, the insider becomes better informed of the prospect of the project (characterized by θ) than the outsider. That is, the information asymmetry takes place at the intermediate date.) More specifically, after using outside financing (i.e. taking later-stage syndication), an unpromising venture capital project may be continued. As the outside investor breaks even, all the costs of inefficiency are borne by the lead investor. Thus the later-stage syndication is not efficient ex-post for the lead VC but it can provide incentive to the entrepreneur ex-ante, which in turn increases the overall project value for the lead VC.

Finally, I argue that the implicit mechanism can be reputation. For example, at T_0, the entrepreneur may choose only the VC who indeed uses later-stage syndication in the previous business. In turn, the VC fund, as one form of a financial intermediary who cares about reputation, has an incentive to realize her commitment to use syndication at a later stage. Syndication, unlike θ which is unobserved by an outsider, is a public signal. Taking syndication at later-stage is helpful in building the future reputation. In contrast, the lead VC's loosening of the ex-post control *privately* by lowering the criterion θ^* *directly* is useless since no outsider can observe θ.

IV.2. Further empirical testing

I provide one more empirical prediction for further testing the model. The model predicts that syndication is highly related to external risk but is unrelated to internal risk. In fact, as I have shown, outside financing other than monetary compensation is needed to incentivize the entrepreneur to provide effort precisely because of the presence of the external risk involved in the project. Hence the model predicts that the later-stage syndication is more likely to occur if there is higher external risk involved in the project beyond the control of the entrepreneur, but it is unrelated to internal risk. (In contrast, if risk aversion is the reason, the later-stage syndication will be positively related to *both* external and internal risk.) In Kaplan and Stromberg (2004), the authors empirically distinguish the external and the internal risk in the VC project and then study their relations to the entrepreneur's compensation and VC control. With a similar methodology (and perhaps using a large sample of data), the model can be tested by studying the relationship between the likelihood of later-stage syndication and the degree of external risk and internal risk in the VC project.

V. Conclusion

This paper provides a novel theory of syndication in venture capital financing. It shows that later-stage syndication is a mechanism to alleviate the inefficiency of pure stage financing. The combined use of later-stage syndication with stage financing is more efficient than the pure stage financing. The theory can explain well why stage financing in reality is typically combined with syndication, and in particular why syndication is more likely to take place at a later stage.

The sub-optimality of pure stage financing is the result of stage financing inducing tight ex-post control by the venture capitalist, which disincentivizes the entrepreneur's effort provision ex-ante, which in turn lowers firm value. The disincentive effect of tight ex-post control, however, in the end is attributed to the special nature of venture capital investment: huge external risk besides internal risk, high private benefit (for the entrepreneur) besides his monetary utility. Under these features, monetary performance-based compensation is not sufficient (to incentivize the entrepreneur). Using later-stage syndication under asymmetric information (thus loosening ex-post control) in addition to performance-based compensation is a better strategy. This subtle mechanism can be regarded as one of the responses by the venture capitalist to the particular challenges of venture capital financing: high risks, severe informational problems and various incentive issues.

Finally, admittedly, in practice venture capitalists are commonly believed to have a financing and an advisory function, while in my model VC only provides financing but does not otherwise contribute to the project. Hence, my model only explores one aspect of the venture capital financing while abstracting from the other one. But it is impossible for one economics (finance) model to explore every facet of reality. Again, the theory in this paper can be seen as complementary to the existing venture capital theories that explicitly model the advisory role of VC like in Fluck, Garrison and Myers (2005) and Cassamatta (2003).

Appendix: proof

Proof of Theorem 2: I only need to prove that the entrepreneur's utility under the pure stage financing is less than that under the second-best. Since $\theta^*_{SB} < \theta^*_{ep}$, I have $e^*_{SB} > a^*_{ep}$ where e^*_{ep} is the entrepreneur's effort under the pure stage financing. Therefore, $U(e^*_{SB}) = [e^*_{SB} \cdot \int_{\theta=\theta^*_{SB}}^{\theta=1} g(\theta)d\theta] - \Psi(e^*_{SB}) \geq [\theta^*_{ep} \cdot \int_{\theta=\theta^*_{SB}}^{\theta=1} g(\theta)d\theta] - \Psi(\theta^*_{ep}) > [\theta^*_{ep} \cdot \int_{\theta=\theta^*_{ep}}^{\theta=1} g(\theta)d\theta] - \Psi(\theta^*_{ep})$. Q.E.D.

Proof of Lemma 3: The continuity is trivial since all the functions involved are regular and continuous. To prove monotonicity, I need to show that if $F_{new} < F_{old}$, then $\theta^*_{new} > \theta^*_{old}$, where θ^*_{new} and θ^*_{old} denote $\theta^*(F_{new})$ and $\theta^*(F_{old})$ respectively. Note that $s(x)(= \begin{cases} 0 & \text{when } x = 0 \\ K & \text{when } x = \bar{X} \end{cases})$ can be alternatively expressed as $s(x) = \min(x, K)$.

From (10), I have $\int_{\theta=\theta^*_{old}}^{\theta=1} \{E[(\min(\tilde{x}, K_{old})|\theta] - F_{old}\} \cdot g(\theta)d\theta = 0$ and $\int_{\theta=\theta^*_{new}}^{\theta=1} \{E[(\min(\tilde{x}, K_{new})|\theta] - F_{new}\} \cdot g(\theta)d\theta = 0$. Hence, $\int_{\theta=\theta^*_{old}}^{\theta=\theta^*_{new}} \{E[(\min(\tilde{x}, K_{old})|\theta] - F_{old}\} \cdot g(\theta)d\theta + \int_{\theta=\theta^*_{new}}^{\theta=1} \{E[(\min(\tilde{x}, K_{old})|\theta] - F_{old}\} \cdot g(\theta)d\theta - \int_{\theta=\theta^*_{new}}^{\theta=1} \{E[(\min(\tilde{x}, K_{new})|\theta] - F_{new}\} \cdot g(\theta)d\theta = 0$

Rewrite the above equation, I obtain,

$$\int_{\theta=\theta^*_{old}}^{\theta=\theta^*_{new}} \{E[(\min(\tilde{x}, K_{old})|\theta] - F_{old}\} \cdot g(\theta)d\theta + \int_{\theta=\theta^*_{new}}^{\theta=1} \{E[\min(\tilde{x}, K_{old}) - \min(\tilde{x}, K_{new})|\theta] - (F_{old} - F_{new})\} \cdot g(\theta)d\theta = 0 \qquad (13)$$

Clearly, from $F_{new} < F_{old}$, I have $K_{old} > K_{new}$. Thus $\min(\tilde{x}, K_{old}) - \min(\tilde{x}, K_{new})$ is an increasing function as $x \in \{0, \tilde{X}\}$. Therefore, $E[\min(\tilde{x}, K_{old}) - \min(\tilde{x}, K_{new})|\theta]$ is increasing of θ. As $\theta^*_{new} \rightarrow \theta^*_{old}$, the first term in (13) approaches 0 and the second-term approaches $\int_{\theta=\theta^*_{old}}^{\theta=1} \{E[\min(\tilde{x}, K_{old}) - \min(\tilde{x}, K_{new})|\theta] - (F_{old} - F_{new})\} \cdot g(\theta)d\theta$. Thus I get $\int_{\theta=\theta^*_{old}}^{\theta=1} \{E[\min(\tilde{x}, K_{old}) - \min(\tilde{x}, K_{new})|\theta] - (F_{old} - F_{new})\} \cdot g(\theta)d\theta = 0$, which means $E[\min(\tilde{x}, K_{old}) - \min(\tilde{x}, K_{new})|\theta^*_{old}] < F_{old} - F_{new}$.

By (9), we know $E[(\max(0, \tilde{x} - K_{new})|\theta^*_{new}] = I_2 - F_{new}$. But $E[(\max(0, \tilde{x} - K_{new})|\theta^*_{old}] = E[(\max(0, \tilde{x} -$

$K_{old})|\theta^*_{old}]-E[\max(0,\tilde{x}-K_{old})-\max(0,\tilde{x}-K_{new})|\theta^*_{old}] = (I_2-F_{old})+E[\min(\tilde{x},K_{old})-\min(\tilde{x},K_{new})|\theta^*_{old}] <$ $(I_2 - F_{old}) + (F_{old} - F_{new}) = I_2 - F_{new}$.

Therefore, $\theta^*_{new} > \theta^*_{old}$. Q.E.D.

Proof of Theorem 3: First of all, let us consider the VC's choose of θ when $F = 0$. In this case, the firm is without syndicate financing. The VC's criterion to choose θ^* becomes $\theta^*(0) = \min\{\theta|E(\tilde{x}|\theta) \geq I_2\}=\theta^*_{ep}$. By $\theta^*_{ep} > \theta^*_{SB}$, I get $\theta^*(0) > \theta^*_{SB}$.

Secondly, let us consider the other extreme case: $F = I_2$. In this case, the lead VC's criterion to choose θ^* is $\theta^*(I_2) = \min\{\theta|E[\tilde{x}-s(\tilde{x})|\theta] \geq 0\}$ subject to $\int\limits_{\theta=\theta^*(I_2)}^{\theta=1} \{E[s(\tilde{x})|\theta]-I_2\}\cdot g(\theta)d\theta = 0$. By the assumption $\int\limits_{\theta=0}^{\theta=1} E(\tilde{x}|\theta)\cdot g(\theta)d\theta \leq I_2$, $\theta^*(I_2)$ is implicitly determined by $\int\limits_{\theta=\theta^*(I_2)}^{\theta=1} [E(\tilde{x}|\theta)-I_2]\cdot g(\theta)d\theta = 0$. Now I need to prove $\theta^*(I_2) < \theta^*_{SB}$. If I evaluate the first-order derivative of utility function at $\theta^* = \theta^*(I_2)$, I get

$$\frac{\partial V}{\partial \theta^*}|_{\theta^*=\theta^*(I_2)} = \underbrace{\frac{\partial a}{\partial \theta^*}}_{<0} \underbrace{\int\limits_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - I_2] \cdot g(\theta)d\theta}_{=0} - \underbrace{(E(\tilde{x}|\theta^*) - I_2) \cdot g(\theta^*) \cdot e}_{<0}$$

> 0,

which means $\theta^*_{SB} > \theta^*(I_2)$ considering $\frac{\partial V}{\partial \theta^*}|_{\theta=\theta^*_{SB}} = 0$.

Combining the above two cases, I obtain $\theta^*(0) > \theta^*_{SB} > \theta^*(I_2)$, that is, θ^*_{SB} lies within the range $(\theta^*(I_2), \theta^*(0))$.

Moreover, as $\theta^*(F)$ is continuous and monotonically decreasing of F, there is a unique F^* such that $\theta^*(F^*) = \theta^*_{SB}$. F^* is the unique optimal amount of syndication. Q.E.D.

References

[1] Admati, A. and P. Pfleiderer, 1994, Robust Financial Contracting and the Role of Venture Capitalists, *Journal of Finance,* 49, 371–402.

[2] Aghion, Philippe and Jean Tirole, 1997, Formal and Real Authority in Organizations, *Journal of Political Economy*, 105,1-29.

[3] Axelson, Ulf, Per Stromberg and Michael Weisbach, 2005, The Financial Structure of Private Equity Funds, Working paper, University of Illinois.

[4] Bienz, Carsten, and Julia Hirsch, 2005, The Dynamics of Venture Capital Contracts, working paper.

[5] Bolton, Patrick and David S Scharfstein, 1996, Optimal Debt Structure with Multiple Creditors, *Journal of Political Economy*; 104 (1), 1–26.

[6] Burkart, Mike, Denis Gromb and Fausto Panunzi, 1997, Large Shareholders, monitoring, and the value of the firm, *Quarterly Journal of Economics*, 112, 693-728.

[7] Bygrave, William, 1987, Syndicated investments by venture capital rms : a networking perspective,Journal fo Business Venturing 2, 139-154.

[8] Cassamatta, Catherine, 2003, Financing and Advising: Optimal Financial Contracts with Venture Capitalists, *The Journal of Finance*, 58, 2059-2085.

[9] Cassamatta, C. and C. Haritchabalet, 2004, Learning and Syndication in Venture Capital Investments, mimeo, University of Toulouse.

[10] Cornelli, F. and O. Yosha, 2003, Stage Financing and the role of convertible securities, *Review of Economic Studies*, 70, 1-32.

[11] Dewatripont, M. and Maskin, E.,1995, Credit and Efficiency in Centralized and Decentralized Economies, *Review of Economic Studies,* 62(4), 541-555.

[12] Dewatripont, Mathias and Jean Tirole, 1994, A theory of debt and equity: diversity of securities and manager-shareholder congruence, Quarterly Journal of Economics, 109, 1027-1054.

[13] Fenn, George, Nellie Liang, and Steven Prowse, The Private Equity Industry: An Overview, (Financial Markets, Institutions and Instruments Series, Volume 6, Number 4), Boston, Blackwell Publishers, 1997.

[14] Fluck, Z., K. Garrison, and S. Myers, 2005, Venture Capital Contracting and Syndication: An Experiment in Computational Corporate Finance, NBER Working Paper No. 11624, Boston.

[15] Grossman, S. and O. Hart, 1986, The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration, *Journal of Political Economy*, 94, 691–719

[16] Gompers, P.A.,1995, Optimal Investment, Monitoring, and the Staging of Venture Capital, *Journal of Finance*, 50, December,1461-1489.

[17] Hopp, Christian, 2006, Chance favours the prepared mind: The Determinants of Monitoring and Staging in Venture Capital Financing, SSRN-id887344.

[18] Inderst and Müller, 2004, Capital structure and credit decisions, Mimeo, NYU.

[19] Inderst and Müllet, 2006, Informed lending and security design, *Journal of Finance*, forthcoming.

[20] Innes,1990, Limited liability and incentive contracting with ex-ante action choices, *Journal of Economic Theory*, 52, 45-67.

[21] Kaplan, Steven and Per Strömberg, 2004, Characteristics, Contracts, and Actions: Evidence from Venture Capitalist Analyses, *Journal of Finance*, 59(5), 2177-2210.

[22] Christian Laux, 2001, Project-Specific External Financing and Headquarters Monitoring Incentives, *Journal of Law Econ & Organ*,17: 397-412

[23] Lerner, Josh, 1994, The Syndication of Venture Capital Investments, *Financial Management*, 23, 16-27.

[24] Manigart, S., H. Bruining, P. Desbrieres, H. LandstrÄom, A. Locket, M. Meulemann, U. Hommel, and M. Wright, 2005, The syndication decision of venture capital investments, *Entrepreneurship: Theory & Practice*, forthcoming.

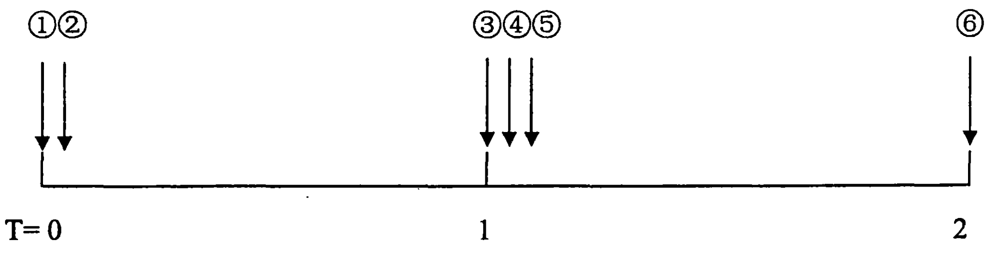
[25] Myers, Stewart C. and N. Majluf, 1984, Corporate financing and investment decisions when firms have information that investors do not have, *Journal of Financial Economics*, 13, 187-222.

[26] Sahlman, W.A., 1990, The Structure and Governance of Venture Capital Organizations, *Journal of Financial Economics*, 27, 473-521.

[27] Sufi, Amir, 2007, Information Asymmetry and Financing Arrangements: Evidence from Syndicated Loans, forthcoming, *Journal of Finance*, Volume 62:2.

[28] Wilson, R., 1968, The Theory of Syndicates, *Econometrica* (January), 119-132.

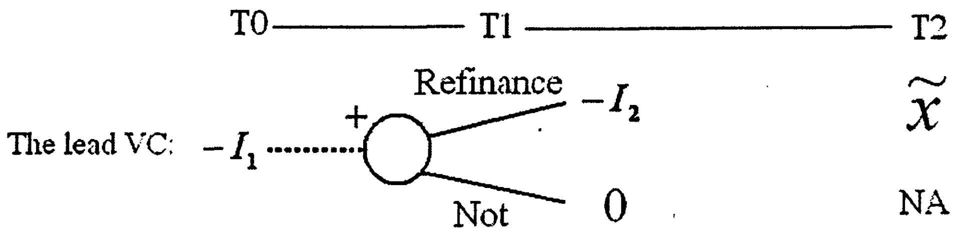
Figure 1: The timeline



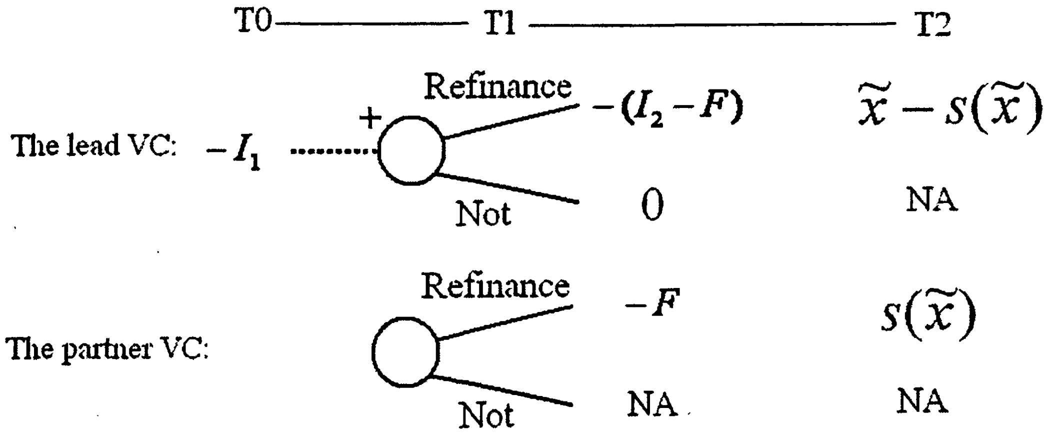
① The VC pays the first round of financing. The project starts.
② The entrepreneur exerts his effort.
③ The VC and the entrepreneur observe the state. If 'Success' state happens, they also receive the signal.
④ The VC makes the refinancing decision.
⑤ If case of refinancing, the VC pays the second round of financing. The project continues.
⑥ Condition on refinancing, the project realizes the final payoff.

Figure 2: The cash flow and decision rights allocation across agents

Without syndication



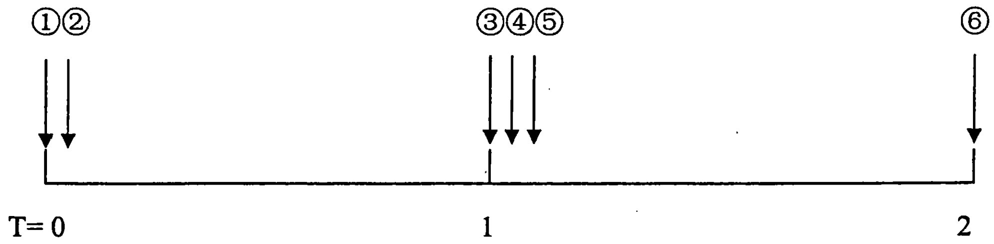
With syndication under financial contract C'



+: Decision right of refinancing or not

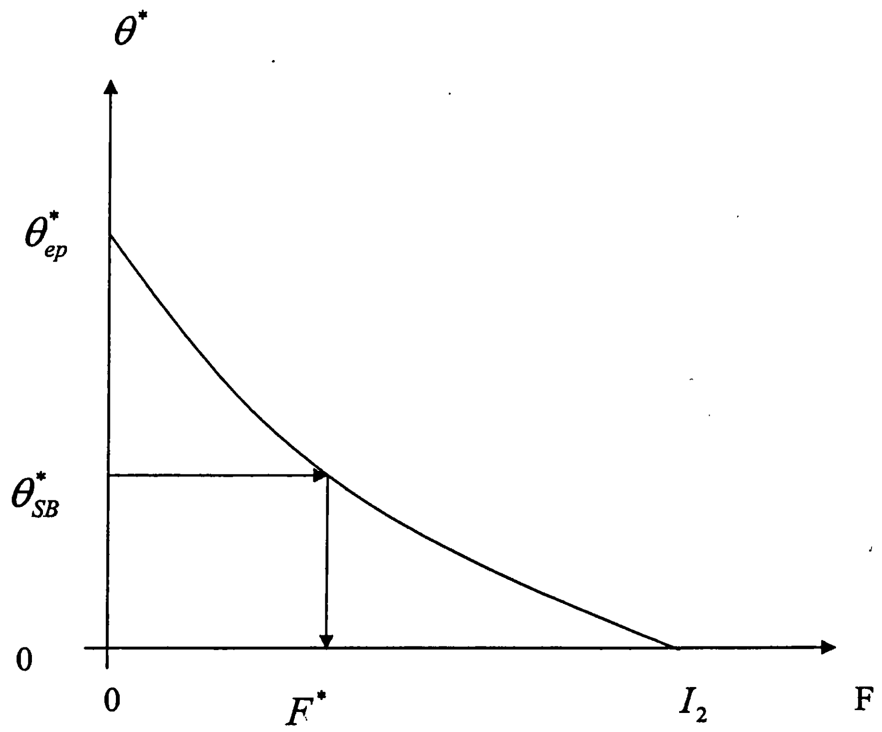
NA: **Not applicable**

Figure 3: The timing line under syndication



① **The lead VC decides the financial structure** and pays the first round of financing. The project starts.
② The entrepreneur exerts his effort.
③ The lead VC and the entrepreneur observe the state. If 'Success' state happens, they also receive the signal.
④ The lead VC makes the refinancing decision.
⑤ If case of refinancing, **the lead VC and the partner VC finance the second round of investment together**. The project continues.
⑥ Condition on refinancing, the project realizes the final payoff, **which is distributed between the lead VC and partner VC.**

Figure 4: The θ^* changes as F changes



The Capital Structure of Private Equity-backed Firms*

Xuewen Liu

London School of Economics

This version: April, 2007

Abstract

In this paper I study one fundamental tension between venture capitalist and management in private equity-backed firms and show capital structure (of private equity-back firms) is a mechanism to resolve the tension. The paper gives rationale for several financial arrangements in private equity investment. (1) Private equity deals are typically partially outside financed even though the private equity fund may not be financially constrained at the deal level. (2) The optimal security for outside financing is debt. (3) The maturity of outside security is long-term. The insight of the paper has applications outside of private equity.

*I am grateful to David Webb, Antoine Faure-Grimaud, Hyun Song Shin, Francesca Cornelli, Denis Gromb, John Hardman Moore, Roman Inderst, Sudipto Bhattacharya, Tianxi Wang, Alexander Bleck, Sridhar Arcot, Jan Bena and seminar participants at LSE for helpful comments at various stages of this project. This is a much revised version of an earlier paper circulated under the title "Managerial incentive, ownership control and external finance".Contact address: Financial markets group, LSE, Houghton Street, London WC2A 2AE, UK. Email: X.liu@lse.ac.uk.

1 Introduction

The *Economist* describes private equity, primarily buyout (LBO) investments, as the new king of capitalism.[1] Up to 2006 private equity fund is responsible for more than $ trillion of investments globally.[2] In deed, in recent years both the volume of overall trading and the size of individual deals have been increasing rapidly. LBO investment nowadays often acts as a key mechanism of corporate restructuring. Despite the unprecedented success and the increased importance of private equity, we have only a limited understanding of the financing and governance structure of private equity.[3]

One of the most remarkable characteristics of buyout investment is the financial structure. Leveraged buyouts, as the name suggests, are usually highly leveraged. The lead theory for why buyout deals need to involve debt leverage is Jensen (1986), who argues the debt in LBOs is to discipline management. But several issues around this financial arrangement remain open. In particular, if the debt is only to discipline management, why is this needed in addition to having the private equity partners monitoring managers? Furthermore, Stulz (1990) presents a formal model for Jensen's idea, where short-term debt rather than long-term debt plays the disciplining role. But most of the time the type of debt used in LBOs is long term (Kaplan and Stein (1993)).

In this paper, I present a model for the capital structure of private equity-backed firms and provide a novel rational for why private equity investment needs to involve outside financing. For a private equity investment (a deal), there usually exists a fundamental tension between management's effort and the lack of commitment by the venture capitalist. The commitment problem arises from the time inconsistency of the venture capitalist's exit or continuation/liquidation decision.[4] Management exerts effort *first,* which influences the probability of 'success' and 'failure' of

[1] The *Economist*, Nov 25th 2004.

[2] Financial Times, July 6th 2006.

[3] One of the reasons has been the opacity of the private equity industry. Private equity, as the name suggests, is largely exempt from public disclosure. As for voluntary disclosure, private equity organizations tend to be extremely reluctant to disclose information about their failures, let alone their successes. See Lerner (1998) and Kaplan and Schoar (2005).

[4] Partnership agreements typically require the fund to be finitely-lived (Sahlman (1990)), which determines that when and how to exit the investment is one of the most important decisions for venture capitalists. It will be clear later on that both the exit and the continuation/liquidation decisions can cause the same problem we are discussing.

the project or the deal (at the intermediate date), and the venture capitalist makes her continuation/liquidation decision *afterwards* when she becomes informed of the state ('success' or 'failure'). If the project is a failure, the venture capitalist will *certainly* liquidate it. If the project is a success, however, the venture capitalist *will not* necessarily continue the project. This is because, conditional on 'success', the project's final payoff is *further* exposed to external risk,[5] e.g. whether the market condition of a successfully-developed new product or an IPO is not as good as initially estimated. The venture capitalist, who only cares about momentary payoffs, will not continue an ex-ante *successful* but ex-post negative forward-looking NPV project. In contrast, management derives *private benefits* from and always prefers continuation. In this case, management exerts higher effort if and only if he anticipates there is a higher probability of continuation upon the success of the project (i.e. his ex-ante effort will not be wasted or expropriated ex-post).

Obviously, management's effort is valuable to the venture capitalist because it can increase the expected value of the project. In order to encourage management to exert effort *ex-ante*, the venture capitalist should commit to continue the project more often than is efficient *ex-post* (upon 'success'). Therefore, there is a tradeoff between ex-ante *high effort* and ex-post *efficient continuation* in maximizing project value at the second-best. However, in a world of incomplete contracting, once management's effort is sunk, the venture capitalist maximizes his own utility by continuing the firm only if it is worth it (i.e. only if the forward-looking NPV is positive). Anticipating this behavior by the venture capitalist, management may choose an effort level lower than the second best. That is, the lack of commitment by the venture capitalist of her exit or continuation/liquidation decision disincentivizes management's ex-ante effort provision. The second best is not attainable.

Using the methodology of mechanism design, I show that capital structure is a mechanism that can resolve the tension and implement the second best. In other words, by changing the capital structure and using outside financing in private equity deals, the venture capitalist commits to her second-best liquidation decision. As for why outside finance can overcome the commitment

[5]Kaplan and Stromberg (2004) give the definition for external risk. VCs and management may face risks that are equally uncertain for both parties. Kaplan and Stromberg (2004) denote such uncertainties as external risks. Examples are the extent of future demand for an undeveloped product, the response of competitors upon the product's introduction, and the receptivity of financial markets when investors try to sell the company or bring it public. In contrast, internal risk refers to uncertainty about which management is better informed than the investor. It relates to asymmetric information and is the main cause of the agency problem.

issue, the mechanism is in the same spirit as the classic problem of financing and investment under asymmetric information. Specifically, I show that after using outside financing from a third party (e.g. bank) who is uninformed about the prospects of the project, the information asymmetry between the venture capitalist and the outside investor will lead to adverse selection.[6] The bad project in a low state of nature may be pooled with the good project and therefore the (unprofitable) bad project may get continued. In short, after using outside financing, the venture capitalist automatically softens her continuation/liquidation decision by continuing the firm more often than in the case where the firm is financed solely by inside equity.

Further, I show that the degree of excessive continuation (i.e. the degree of adverse selection) is determined by two factors: the amount of outside financing and the type of security used. Given the security type (e.g. straight debt or equity), the degree of excessive continuation is *monotonically* increasing in the amount of outside financing. As the second best requires commitment of an optimal degree of excessive continuation, there exists a unique optimal amount of outside financing that can induce the commitment of the second-best, that is, there exists a *unique* optimal capital structure that maximizes the firm value. As for the security type of outside finance, I show that debt is optimal. This is because the debt can help the venture capitalist, who prefers to have a higher return on investment for a given NPV, achieve the highest return among all security types she can choose.

There exists a massive literature studying the capital structure of public firms and providing theories to explain it. Yet these theories look unable to explain the capital structure of firms financed by the private capital market. For example, according to classic capital structure theory, like Myers and Majluf (1984), the firm should avoid using external financing whenever possible because of the agency costs associated with adverse selection. But in the private equity investment, it is the venture capitalist that collects the information upfront and monitors the process of the project afterwards. The outside investors (e.g. banks) are much less informed about the state of the project at the

[6] This is in the same spirit as Myers and Majluf (1984). Inderst and Müller (2006), which studies credit analysis and decisions, also shows that the information asymmetry can lead to the agent's endogenous decision bias. One of key differences, however, is that the borrower has information advantage in my model while in Inderst and Müller (2006)'s model it is the lender. Of course, the main difference lies in that two papers study different questions and there do not exist any moral hazard issues in that paper. This difference also distinguishes my paper with Inderst and Müller (2004) which studies banks' loan decision and does not involve any moral hazard problems.

beginning and over the life of the investment.[7] In other words, there is some information asymmetry between the venture capitalist and the outside investors. According to the classic theory, private equity fund should avoid using outside financing at the deal-level particularly because it is not financially constrained at the deal-level (i.e. the capital raised at the time the fund is formed may be enough to cover the required funding for some deals). Therefore, from these theories, it seems that we cannot answer the question why the private equity investments actually use outside financing at the deal-level. Counterintuitively, nevertheless, this paper shows that the information asymmetry between the venture capitalist and the outside investor is actually good news. Such information asymmetry is introduced into the firm *on purpose* in order to achieve efficiency. It can help solve the commitment problem between the venture capitalist and management. This insight is very close to Dewatripont and Maskin (1995), which also suggests that the market friction (in terms of asymmetric information) has merit. Interestingly and importantly, in Dewatripont and Maskin (1995) asymmetric information (more specifically, ex-post moral hazard) is used to avoid ex-ante adverse selection while in my paper asymmetric information (more specifically, ex-post adverse selection) is to alleviate ex-ante moral hazard.

The lead article studying the financial structure of private equity investment is Axelson, Stromberg and Weisbach (2005). That paper also provides a rationale for why private equity firms raise additional capital from an outsider at the deal level after the formation of the fund. However the motivations of outside financing in that paper and this paper are different. In Axelson, Stromberg and Weisbach (2005), outside financing helps alleviate an adverse selection problem, i.e. capital markets can take into account of public information to discipline general partners to choose more promising projects. In contrast, in my paper, outside financing helps solve a moral hazard problem, i.e. allows the better provision of incentives.[8]

Finally, in corporate control literature there are several papers studying the lack of commitment

[7] Axelson, Stromberg and Weisbach (2005) write: "venture deals are often syndicated, with a lead venture capitalist raising funds from partners, who presumably take account of, at a minimum, information on the state of the economy and industry in the same way that banks providing financing to buyouts do."

[8] Furthermore, the central questions studied in two papers are different. In Axelson, Stromberg and Weisbach (2005), the authors model how the financial structure of private equity funds can mitigate the agency problem between limited partners and general partners. In contrast, in my paper, I emphasize how the financial structure of private equity investment can solve the agency problem between management and general partners.

as a source of inefficiency in a firm and analyzing its solution. Following Aghion and Bolton (1992), Dewatripont and Tirole (1994) show that switching control rights between the heterogeneous outside investors is a commitment mechanism. In my paper, there is no control rights switch between investors. The venture capitalist is endowed with full control rights. But in Dewatripont and Tirole (1994) there is no information asymmetry between the different investors. Burkart, Gromb and Panunzi (1997) argue that ownership concentration is a way to induce commitment. In contrast, in my paper, I show that outside financing under information asymmetry can work as a commitment mechanism. Importantly, however, my paper is close to Burkart, Gromb and Panunzi (1997) in sense that both papers show there exists a *unique* optimal implementation of the second-best. In Burkart, Gromb and Panunzi (1997) the unique optimal tradeoff between ownership control and management incentive demands a unique optimal ownership concentration while in my paper it requires a unique optimal amount of outside financing.

The remainder of the paper is organized as follows. Section 2 introduces the model setup and the benchmark model where there is a tension between management's effort and the lack of commitment by the venture capitalist. In section 3, I show how capital structure can be a mechanism to induce commitment and thus resolve the tension. Section 4 discusses the robustness of the model. In Section 5, I make the conclusion.

2 The model

2.1 *The setup*

The model is cast in a simple framework of contract incompleteness and risk neutrality. There are three dates in the model - T_0, T_1 and T_2. The net risk-free interest rate in the economy is normalized to 0 while the subjective time discount factors are assumed to be 1 (alternatively, time is short).

Consider a buyout project of private equity investment. The project requires an investment of I at T_0. At T_0 management needs to exert his effort e (where $e \in [0,1]$) to boost the project's prospects. Specifically, the effort influences the probability of the realization of two states ('Success' and 'Failure') at T_1. The probability for 'Success' to happen is e (equal to effort) while the probability for 'Failure' is $1 - e$. The states are observable by management and the investor (i.e. venture capitalist) but not by any third party.[9] In the 'Failure' state, the project realizes 0 final payoff at T_2 with probability 1. In the 'Success' state, the final payoff at T_2 is a random variable $\tilde{x}$ with density as $f(x|\theta)$, where θ is the signal that the investor receives at T_1. The density $f(x|\theta)$ is positive in the support $[0, \bar{X}]$ and satisfies the Monotone Likelihood Ratio Property(MLRP) with respect to θ. $\tilde{\theta}$ has density $g(\theta)$ in the support $[0, 1]$.

Two comments on the signal θ are in order. Firstly, the signal distribution $g(\theta)$ is exogenous, which means that, conditional on the 'Success' state, the realization of θ at T_1 is independent of management's *ex-ante* effort. I use this setup to capture the feature that the project's final payoff not only depends on management's effort but also is exposed to some external risk characterized by θ. Examples of external risk are the extent of future demand for an undeveloped product, the response of competitors upon the product's introduction, and the receptivity of financial markets when the investor try to sell the company or bring it public (Kaplan and Stromberg (2004)).[10] Secondly, I assume that the signal θ may or may not be observable by management. In the following discussion, I use the weaker assumption: θ can be observable by management.[11] But I assume θ is definitely *not* observable by a third party. Therefore, θ is uncontractible.

[9] The states are uncontractible since they cannot be observed by a third party. But this assumption is not crucial to the result and is only for the purpose of simplicity. Alternatively I can assume that the states are contractible. The result of model doesn't change.

[10] Kaplan and Stromberg (2004) define external risks as risks that are equally uncertain for the investor and management. In my setup, both parties are equally uncertain about the realization of θ. Also, in my setup, the state ('Success' or 'Failure') is the internal risk. Kaplan and Stromberg (2004) define internal risk as uncertainties about which management is better informed than the investor. It relates to asymmetric information and is the main cause of agency problem. Indeed, in my setup, management is better informed of the probability of the realization of the states ('Success' or 'Failure') than the investor. In fact, management can affect the realization of the states (by his own effort) to some extent while the investor cannot observe management's effort and hence she is totally uncertain about the realization of the states.

[11] The assumption that the signal θ is observable by management is weaker than the signal θ being unobservable by management. In the latter case, the model becomes an incomplete contract framework, which can simplify the analysis of the model. Nevertheless, even the stronger assumption - the unobservability of θ by management - is still realistic and justifiable. For example, it is normal that only the venture capitalist but not management has an idea about the future value of a firm or a new product when bringing it to the IPO or market. This may be due to the more extensive business experience and/or expertise of the venture capitalist.

At T_1, the investor needs to make her liquidation/continuation decision. In the case of liquidation, the project realizes its liquidation value L $(0 < L \leq I)$ at T_1 in either state.[12] In the case of continuation, the project realizes its cash flow at T_2 . As I will show, in the 'Failure' state it is optimal for the investor to liquidate the project. The key decision for the investor at T_1 is whether she should continue the project in the 'Success' state after she receives the signal θ. Suppose the investor uses a simple 'switch' strategy and sets the threshold to θ^* (i.e. she continues the project if and only if $\theta \geq \theta^*$). Then the probability of the project's continuation at T_1 conditional on the 'Success' state is $p = \int_{\theta=\theta^*}^{\theta=1} g(\theta)d\theta$. Hence the *ex-ante* probability of the project's continuation is $e \cdot p$. To rule out trivial cases, I assume $E(\tilde{x}|\theta = 0) < L < E(\tilde{x}|\theta = 1)$. Without loss of generality, I also assume $\int_{\theta=0}^{\theta=1} E(\tilde{x}|\theta) \cdot g(\theta)d\theta \leq L$.[13]

Figure 1 describes the timeline.

(Insert Figure 1 here)

I assume management derives utility from his private benefit in *continuation*.[14] Specifically, management's *ex-ante* utility function is assumed to be $U(e) = B \times (e \times p) - \Psi(e)$, where B is his private benefit from *continuation*. The term $e \times p$ is the probability that he anticipates the investor will continue the firm at T_1 while the term $\Psi(e)$ is management's disutility from exerting effort, which satisfies the standard conditions $\Psi'(e) > 0$ and $\Psi''(e) > 0$. Moreover, $\Psi(0) = 0, \Psi'(0) = 0$ and $\Psi(1) = +\infty$. At this stage I abstract from management's monetary compensation by normalizing

[12]Under the alternative assumption that the liquidation values in the 'Success' and 'Failure' state are different, our main result does not change. Nevertheless, one justification for why the firm has the same liquidation value in two states is that the firm holds the same firm-non-specific assets in both states although the firm-specific assets may be different. While only firm-non-specific assets can realize the liquidation value by being sold to other firms, the liquidation value is the same in the two states.

[13]In fact, this assumption is not a necessary condition to derive the result of the paper. The only purpose for using this assumption is to rule out some uninteresting cases. The weaker assumption $E(\tilde{x}|\theta = 0) < L$ is sufficient to derive the result. It will be clear later on that the uninteresting case is $\theta^*_{SB} = 0$. Please refer to footnote 20.

[14]Naturally management (entrepreneur) has high private benefits if his new product is commercialized and/or his firm is brought to the IPO. Also, he cares about the loss of reputation if he is dismissed at T_1. The idea is in the same spirit as Jensen (1986). Management is an empire builder, who always wants to have a big project, regardless of whether it is profitable or not. This specification also captures the nature of management interests in presence of separation between ownership and control. In the tradition of Hart and Moore (1990), managers' utility is proportional to the amount of resources directly under their control, while, at the same time, they enjoy a rent for which they can't be made pay for (as in Jensen (1986)).

it to 0 at T_1 and T_2. Actually I will show that no compensation scheme (state-contingent or not) can solve the *commitment problem*, hence compensation is insufficient in the sense that it cannot eliminate the inefficiency I am considering. At this stage, we can think of the private benefit B as being high enough to make any monetary payoff negligible, hence management's monetary payoff does not enter his utility function. Hereafter I normalize B to unity (i.e. $B \equiv 1$). By the first order condition: $U'(e) = p - \Psi'(e) = 0$, e is an increasing function with respect to p (as $e = \Psi'^{-1}(p)$ is increasing). That is, the higher the probability that the investor will continue the project, the higher the management's effort. Clearly, the highest effort that the investor can incentivize management to make is $\bar{e} = \Psi'^{-1}(1)$ considering $p \leq 1$.

It is important to note that the continuation/liquidation decision is interpreted in a broad sense. For example, the continuation/liquidation decision can be *alternatively* interpreted as the exit decision by the investor. The two main exit routes in the private equity investment are an IPO and a private sale. In reality, most venture capital agreements provide for mergers or trade sale (in contrast with an IPO) as a liquidation event. In my setup, I can interpret continuation as the exit via an IPO while liquidation corresponds to an exit via an (early) private sale. As Fenn, Liang and Prowse (1997) point out, company management favors the IPO because it preserves the firm's independence. It is natural to assume that management has private benefits from continuation (i.e. public offer).

I assume that the investor only cares about her monetary payoff. Her utility is the net monetary payoff of her investment.

2.2 *The benchmark: the project is fully inside financed*

As a benchmark, in this section I assume that the project is fully inside financed. That is, the investor pays the full I at T_0. If this is the case, the investor's utility is equal to the NPV of the project. Her utility as a function of θ^* can be expressed by:

$$V(\theta^*) = \overbrace{-I}^{\substack{\text{The}\\\text{investment}\\\text{at } T_0}} + \overbrace{(1-e)L}^{\substack{\text{The expected}\\\text{liquidation value}\\\text{in the 'Failure'}\\\text{state at } T_1}} + e[\overbrace{\int_{\theta=0}^{\theta=\theta^*} L \cdot g(\theta) d\theta L}^{\substack{\text{The expected}\\\text{liquidation value at}\\T_1 \text{ for a low } \theta \text{ in}\\\text{the 'Success' state}}} + \overbrace{\int_{\theta=\theta^*}^{\theta=1} E(\tilde{x}|\theta) \cdot g(\theta) d\theta}^{\substack{\text{The expected final}\\\text{payoff at } T_2 \text{ for}\\\text{a high } \theta \text{ in the}\\\text{'Success' state}}}]$$

$$= \overbrace{-(I-L)}^{\substack{\text{The value-added in}\\\text{the first period}}} + e \overbrace{\int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - L] \cdot g(\theta) d\theta}^{\substack{\text{The expected value-added}\\\text{in the second period}}}$$

Given I and L, the investor's utility function depends on management's *ex-ante* effort e and the investor's *ex-post* control θ^*. From the ex-ante perspective, in order to give management the highest incentive to exert effort, the investor's control decision should be $\theta^*_{et} = 0$,[15] where θ^*_{et} denotes the investor's decision to achieve highest *ex-ante* effort. In contrast, after management's effort has been sunk (i.e. e is given), the investor's *ex-post* efficient control should be $\theta^*_{ep} = \min\{\theta | E(\tilde{x}|\theta) \geq L\}$.[16] That is, *ex-post*, the investor should continue the project if and only if the project's expected payoff at T_2 is higher than the opportunity cost of continuing - the liquidation value L.[17]

(Insert Figure 2 here)

---

[15] This is the result of the optimization problem:

$$\underset{\theta^*}{Max}\ e$$
$$\equiv \underset{\theta^*}{Max}\ \Psi'^{-1}\left(\int_{\theta=\theta^*}^{\theta=1} g(\theta)d\theta\right)$$

[16] This is the result of the optimization problem:

$$\underset{\theta^*}{Max}\ V(\theta^*)$$
$$\equiv \underset{\theta^*}{Max} - (I-L) + e\int_{\theta=\theta^*}^{\theta=1} (E(\tilde{x}|\theta) - L) \cdot g(\theta)d\theta$$

where e is a constant.

[17] Also, here I can justify that the 'liquidation' is the investor's optimal strategy in 'Failure' state both ex-ante and ex-post. Ex-post, the liquidation value L at T_1 is higher than cash flow 0 at T_2. Note that the investor loses the liquidation value L in the case of continuation. Ex-ante, the investor must threaten to liquidate the project in order to incentivize management to exert effort.

By assumption ($E(\tilde{x}|\theta=0)<L$), I have $\theta^*_{et}<\theta^*_{ep}$. The fact that θ^*_{et} is not equal to θ^*_{ep} demonstrates that the investor cannot achieve the *ex-ante* highest incentive and *ex-post* efficient control *simultaneously.* Further, as θ^* moves from θ^*_{et} to θ^*_{ep} in the interval $[\theta^*_{et}, \theta^*_{ep}]$, the *ex-ante incentive* efficiency (the e term) decreases while the *ex-post control* efficiency (the term $\int_{\theta=\theta^*}^{\theta=1}(E(\tilde{x}|\theta)-L)\cdot g(\theta)d\theta$) increases. The highest overall efficiency should be the result of the trade-off between these two efficiencies. Figure 2 expresses the idea of the trade-off between incentive and control.[18] Naturally, in the world where θ is contractable, such a trade-off is feasible.

If θ^* is contractable, the investor's problem is to find an optimal θ^* to be contracted to maximize her utility. Program 1 solves such a problem:

Program 1 ($P1$):

$$\underset{\theta^*}{Max} V(\theta^*)$$

$$\equiv \underset{\theta^*}{Max} \quad -(I-L)+e\int_{\theta=\theta^*}^{\theta=1}[E(\tilde{x}|\theta)-L]\cdot g(\theta)d\theta \tag{1}$$

$$\equiv \underset{\theta^*}{Max} \quad e\int_{\theta=\theta^*}^{\theta=1}[E(\tilde{x}|\theta)-L]\cdot g(\theta)d\theta \tag{2}$$

$$s.t. \quad \int_{\theta=\theta^*}^{\theta=1} g(\theta)d\theta=\Psi'(e) \qquad \text{(IC of management)} \tag{3}$$

I denote the optimal θ^* in the above program as θ^*_{SB} and the utility V at the optimum as V_{SB}.[19]

I can prove that $\theta^*_{SB}<\theta^*_{ep}$. In fact, if I evaluate the first-order derivative of the investor's utility function at θ^*_{ep}, I obtain

$$\frac{\partial V}{\partial \theta^*}|_{\theta^*=\theta^*_{ep}}=\underbrace{\frac{\partial e}{\partial \theta^*}}_{<0}\underbrace{\int_{\theta=\theta^*}^{\theta=1}[E(\tilde{x}|\theta)-L]\cdot g(\theta)d\theta}_{>0}-\underbrace{[E(\tilde{x}|\theta^*)-L]\cdot g(\theta^*)\cdot e}_{=0}$$

$$<0,$$

which means that there is scope to decrease θ^*_{ep} to increase the utility, that is,

$$\theta^*_{SB}<\theta^*_{ep} \text{ and } V(\theta^*_{ep})<V_{SB}.^{20} \tag{4}$$

[18] Here control refers to real control rather than formal control. Aghion and Tirole (1997) distinguish the formal and real control.

[19] I assume that V_{SB} is positive. That is, the investor's ex-ante net payoff is positive.

I define the outcome vector (θ^*_{SB}, V_{SB}) determined by Program 1 as the Second-best. Formally,

Definition 1 *(Second-best): If there is an equilibrium in which the outcome vector (θ^*, V) is identical to (θ^*_{SB}, V_{SB}), then we say that this equilibrium achieves the second-best.*

Now let us consider the case where the θ is uncontractable, which is the assumption of our setup. In fact, as management moves first (exerting his effort), the investor moves later (choosing her liquidation decision), and the investor cannot *commit* not to pursue her ex-post efficient liquidation decision θ^*_{ep} after management's effort has been sunk, the unique (subgame perfect nash) equilibrium for this sequential game is that the investor chooses the θ^* as θ^*_{ep} (i.e. ex-post efficiency).

From (4), we know that the investor's utility under ex-post efficiency is lower than that under the second-best. Moreover, since management exerts less effort under ex-post efficiency than under the second-best, management's utility decreases as well. Therefore, the second-best strictly Pareto dominates the fully-inside-financing equilibrium.

I summarize the above results in Theorem 1.

Theorem 1 *The equilibrium when the project is fully inside financed is strictly sub-optimal relative to the second-best in terms of maximizing the investor's utility. Moreover, from the viewpoint of social welfare, the second-best strictly Pareto dominates the fully-inside-financing equilibrium.*

Proof: see the Appendix.

The fact that the fully-inside-financing equilibrium is strictly sub-optimal relative to the second-best highlights the necessity of the investor's commitment to give up some ex-post control (i.e. commit to more often continuation than is efficient), which can boost ex-ante incentive. However,

[20] Similarly, by the assumption $\int_{\theta=0}^{\theta=1} E(\tilde{x}|\theta) \cdot g(\theta) d\theta \leq L$, I can also show that $\theta^*_{SB} > 0$. In fact, $\frac{\partial V}{\partial \theta^*}|_{\theta^*=0} = \underbrace{\frac{\partial e}{\partial \theta^*}}_{<0}$ $\underbrace{\int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta) - L] \cdot g(\theta) d\theta}_{\leq 0} - \underbrace{[E(\tilde{x}|\theta^*) - L] \cdot g(\theta^*) \cdot e}_{<0} > 0.$

in the θ-uncontractable world, the investor lacks the mechanism to commit to such a concession, which in turn induces management to exert less than the second-best effort level. This, in the end, reduces the investor's welfare. In the next section, I will show that the outside financing can actually form a mechanism that enables the investor's commitment making the second-best implementable.

3 The implementation: the second-best is implementable via contract design

In this section, I show that capital structure can overcome the commitment issue. Hereafter, I presume that there is also an outside investor who participates in financing the project from T_0 and who is uninformed of the signal θ. The outside investor corresponds to banks in LBOs. I show that after introducing the uninformed third party to jointly finance the project, the lead investor will automatically continue the firm more often. The second-best is implementable.

3.1 *The financial contract*

Before I provide a formal proof of the implementation, I need to discuss the financial contract regarding the private equity-backed firm we are considering. Specifically, I define financial contract C', whose terms are summarized in Figure 3.

Definition 2 *The financial contract of the firm is a vector* $C := (\{(\{(CF_t^j, CR_t^j)\}_{t=0}^2)\}_{j=1}^J)$, *where* J *is the number of claimants.* $CF_t^j (\in R)$ *is the cash flow for claimant* j *at time* t*; it can be positive, zero or negative.* CR_t^j $(\subset SD_t)$ *is the decision right endowed to claimant* j *at time* t *where* SD_t *is the set of all decisions made for the firm at time* t*.*

Definition 3 *I define* $\{C'\}$, *which is a contract subspace of* $\{C\}$ *such that*

$J = 2$

and

$$C' = (((CF_0^E, CR_0^E),(CF_1^E, CR_1^E),(CF_2^E, CR_2^E)), ((CF_0^O, CR_0^O),(CF_1^O, CR_1^O),(CF_2^O, CR_2^O)))$$

where $E = lead\ investor$, $O = outside\ investor$;

$CF_0^E = -(I - F)$, $CF_0^O = -F$; $CR_0^E = nothing$, $CR_0^O = nothing$;

$$CF_1^E = \begin{cases} 0 & \text{if firm continues} \\ L - F & \text{if firm is liquidated} \end{cases}, CF_1^O = \begin{cases} 0 & \text{if firm continues} \\ F & \text{if firm is liquidated} \end{cases};$$

$CR_1^E = Liquidation/continuation$, $CR_1^O = nothing$;

$CF_2^E = \tilde{x} - s(\tilde{x})$, $CF_2^O = s(\tilde{x})$; $CR_2^E = nothing$, $CR_2^O = nothing$;

$L \geq F$; (5)

Both $s(\tilde{x})$ and $\tilde{x} - s(\tilde{x})$ are non-negative and non-decreasing with respect to $\tilde{x}$. (6)

(Insert Figure 3 here)

Figure 3 describes the cash flow and control rights allocation under the contract C'. The basic specification of the contract C' can be expressed as follows. There are two security holders: the outside investor who is uninformed of the signal θ and the lead investor. At T_0, the lead investor contributes $I - F$ towards the initial investment while the outside investor contributes the remaining funds F. At T_1 it is up to the lead investor to decider whether to liquidate or continue.[21] In the case of continuation, both parties receive zero cash flow. In the case of liquidation, the outside investor is paid back his initial contribution F from the liquidation value,[22] while the lead investor will claim the residual liquidation value after repaying the outsider, that is $L - F$. At T_2, the lead investor receives the state-contingent claim $\tilde{x} - s(\tilde{x})$ while the outside investor gets the remaining payoff $s(\tilde{x})$. Actually, the only unspecified clauses in the contract C' are F and $s(\tilde{x})$. Hence, hereafter I use the vector $(F, s(\tilde{x}))$ to denote the contract in space $\{C'\}$. I also assume that the

[21] Considering the information structure in our setup where at T_1 only the lead investor and management can observe the signal θ, it is natural to limit the contract space to the one that still gives the liquidation/continuation decision rights to the lead investor rather than the outside investor. It is not optimal to give the decision rights to management, who always wants to continue.

[22] The reason I use this assumption is because the security type I have in mind to model is long-term debt, in which the security holder's claim in the case of early liquidation is the investor's initial investment (i.e. face value). In the extension part of the model, I will discuss the more general mechanism design where there is no exogenous limitation to the amount of repayment to the outside investor in the case of early liquidation.

outside investor is risk-neutral and he joins the financing at competitive terms.[23]

Under the financial contract $(F, s(\tilde{x}))$, the lead investor's utility function becomes

$$V(\theta^*) = \overbrace{-(I-F)}^{\substack{\text{The lead}\\ \text{investor's initial}\\ \text{investment}\\ \text{at } T_0}} + \overbrace{(1-e)(L-F)}^{\substack{\text{The expected}\\ \text{residual}\\ \text{liquidation value}\\ \text{for the lead}\\ \text{investor in the}\\ \text{'Failure' state at } T_1}} + e[\overbrace{\int_{\theta=0}^{\theta=\theta^*} (L-F)\cdot g(\theta)d\theta}^{\substack{\text{The expected}\\ \text{residual liquidation}\\ \text{value for the lead}\\ \text{investor at } T_1\\ \text{for a low } \theta \text{ in}\\ \text{the 'Success' state}}} + \overbrace{\int_{\theta=\theta^*}^{\theta=1} E[\tilde{x}-s(\tilde{x})|\theta]\cdot g(\theta)d\theta}^{\substack{\text{The expected final}\\ \text{payoff for the lead}\\ \text{investor at } T_2 \text{ for}\\ \text{a high } \theta \text{ in the}\\ \text{'Success' state}}}]$$

$$= \overbrace{-(I-L)}^{\substack{\text{The value-added in}\\ \text{the first period}}} + e\cdot \overbrace{\int_{\theta=\theta^*}^{\theta=1} \{E[\tilde{x}-s(\tilde{x})|\theta]-(L-F)\}\cdot g(\theta)d\theta}^{\substack{\text{The expected value-added for}\\ \text{the lead investor in the second period}}} \qquad (7)$$

Ex-post, the lead investor continues the project if and only if her expected payoff at T_2 of continuing is higher than the opportunity cost of continuing, that is,
$\theta^* = \min\{\theta |\ E[\tilde{x} - s(\tilde{x})|\theta] \geq L - F\}$.

As for the outside investor who is **uninformed** of θ, since his reserve utility is zero, the outside investor's participation condition is:

[23]Under the relaxed assumption that the outside investor demands positive rent for financing, the main result of the model does not change.

$$\overbrace{-F}^{\substack{\text{The outsider's}\\ \text{initial}\\ \text{investment}\\ \text{at T}_0}} + \overbrace{(1-e)F}^{\substack{\text{The expected}\\ \text{liquidation}\\ \text{value for the}\\ \text{outsider at } T_1\\ \text{in 'Failure' state}}} + e[\overbrace{\int_{\theta=0}^{\theta=\theta^*} F \cdot g(\theta) d\theta}^{\substack{\text{The expected}\\ \text{liquidation value}\\ \text{for the outsider}\\ \text{at } T_1 \text{ for a}\\ \text{low } \theta \text{ in the}\\ \text{'Success' state}}} + \overbrace{\int_{\theta=\theta^*}^{\theta=1} E[s(\tilde{x})|\theta] \cdot g(\theta) d\theta}^{\substack{\text{The expected}\\ \text{final payoff}\\ \text{for the outsider}\\ \text{at } T_2 \text{ for a}\\ \text{high } \theta \text{ in the}\\ \text{'Success' state}}}] = 0.$$ [24]

Rewriting the above equation, we have:

$$e \cdot [\int_{\theta=\theta^*}^{\theta=1} (E[s(\tilde{x})|\theta] - F) \cdot g(\theta) d\theta] = 0 \,. \tag{8}$$

As for management, since he is not the agent in the contract $(F, s(\tilde{x}))$, his decision is still governed by his (IC) condition (3).

3.2 *Implementing the second-best with the financial contract*

The lead investor decides the financial structure (that is, chooses the financial contract $(F, s(\tilde{x}))$) at T_0 when the investment takes place. Such a decision is made *before* management's decision to exert effort. Figure (4) describes the new timeline.

(Insert Figure 4 here)

As the outside investor breaks even and receives zero surplus, the lead investor will obtain the same surplus and utility under the financial contract $(F, s(\tilde{x}))$ as at the second best if she chooses θ^* as θ^*_{SB}.

Formally,

Lemma 1 *Under the financial contract $(F, s(\tilde{x}))$, if θ^*_{SB} is implemented in equilibrium, then V_{SB} will be automatically implemented.*

[24] The outside investor's participation constraint is binding in our case.

Proof: If we add the LHS of (8) to the RHS (7), we obtain

$$V(\theta^*) = -(I-L) + e\int_{\theta=\theta^*}^{\theta=1} [E(\tilde{x}|\theta)-L]\cdot g(\theta)d\theta \tag{9}$$

which is identical with the objective function (1) in ($P1$). Therefore, if θ^*_{SB} is implemented (hence e under the second best is implemented), V_{SB} will be implemented. Q.E.D.

From Lemma 1, we can conclude that in order to implement the second-best we only need to implement θ^* at θ^*_{SB}. Further, from the analysis in the last subsection, we know that θ^* under the financial contract $(F, s(\tilde{x}))$ is determined by the following joint equations

$$\begin{cases} \theta^* = \min\{\theta | E[\tilde{x} - s(\tilde{x})|\theta] \geq L - F\} & \text{(the lead investor's rational choice)} \quad (10) \\ \int_{\theta=\theta^*}^{\theta=1} (E[s(\tilde{x})|\theta] - F)\cdot g(\theta)d\theta = 0 & \text{(IR of the outside investor)} \quad (11) \end{cases}$$

Essentially, θ^* is determined jointly by F and $s(\tilde{x})$. I denote the map from $(F,\ s(\tilde{x}))$ to θ^* as $\theta^*_s(F)$. Recall that F is the amount of outside financing and $s(x)$ is its security type. Now the implementation problem of the second best is converted to the problem whether we can find a combination $(F,\ s(\tilde{x}))$ such that $\theta^*_s(F) = \theta^*_{SB}$.

I discuss several properties of $\theta^*_s(F)$ first.

Lemma 2 *If $F > 0$, for any security type $s(x)$ of outside financing, θ^* is downward biased (i.e. $\theta^*_s(F) < \theta^*_{ep}$).*

I provide the mathematical proof first. As the lead investor is not able to offer a strictly flat payoff (i.e. $s(x)$ could not be a constant) to the outside investor at T_2 due to the lead investor's limited liability and $x \in [0, \bar{X}]$, $s(x)$ must strictly increase in some non-zero-measure subset of $[0, \bar{X}]$, hence $s(x)$ becomes an information-sensitive security.[25] A higher θ will lead to higher $E[s(\tilde{x})|\theta]$. From (11), we know that the outsider claims F on average for all θ in $[\theta^*_s(F), 1]$. Therefore, the claim for the lowest signal $\theta^*_s(F)$ must be lower than F, that is, $E[s(\tilde{x})|\theta^*_s(F)] < F$. While we have $E[\tilde{x} - s(\tilde{x})|\theta^*_s(F)] = L - F$ by (10), $E[\tilde{x}|\theta^*_s(F)]$, which equals $E[s(\tilde{x})|\theta^*_s(F)] + E[\tilde{x} - s(\tilde{x})|\theta^*_s(F)]$,

[25] The (log) expected value of $s(\tilde{x})$ conditional on the signal θ changes as θ changes. Mathematically, $\frac{\partial \log E[s(\tilde{x})|\theta]}{\partial\theta} > 0$.

must be lower than L. Combining the above result with $E(\tilde{x}|\theta^*_{ep}) = L$, the relation $\theta^*_s(F) < \theta^*_{ep}$ follows.

The fundamental reason for the lead investor's ex-post decision bias is due to the information asymmetry between the lead investor and the outside investor. The outside financing under asymmetric information leads to adverse selection (Myers and Majluf (1984)). In fact, after the initial date T_0's investment I has been sunk, the lead VC's (forward-looking) refinancing decision at T_1 is a one-period investment decision: whether to invest a project with the investment (*opportunity*) cost as L and payoff as $\tilde{x}$ at the next date. By Myers and Majluf (1984), if the project is fully *internally* financed (i.e. the lead investor solely occupies the entire cash flows -L and $\tilde{x}$), the efficient separating equilibrium is achieved, i.e. the project is financed and invested if and only if it is profitable, that is, if and only if $E[\tilde{x}|\theta] \geq L$. Note that the project type in my setup is characterized and indexed by the continuous real number θ. However, if the lead investor uses *external finance* from an uninformed outsider (i.e. L as well as $\tilde{x}$ is splited between the lead investor and the outside investor), from Myers and Majluf (1984), adverse selection with inefficient pooling will happen. That is, some unprofitable bad types of project (with a low θ), which are 'subsidized' by the good types (with a high θ), will necessarily be continued. This inefficient pooling is the fundamental reason for the lead investor's decision bias when outside financing is used in our model.

By Myers and Majluf (1984), the degree of adverse selection is determined by two factors: the amount of outside financing and the type of security used. Given the amount of the outside finance, the straight debt leads to the lowest degree of adverse selection. In the context of our model, the degree of adverse selection is the degree of excessive continuation. We have

Lemma 3 *Given F, if $s(x)$ is straight debt, θ^* is the least downward biased (i.e. $\theta^*_s(F)$ is closest to θ^*_{ep} among all θ^*s satisfying (10) and (11)).*

In fact, by MLRP, we know that if $s(x)$ is the straight debt (i.e. the payoff function of straight debt is $s(x) \equiv \min(K, x)$ where K is the face value), it is the *least information-sensitive* security. From the proof of Lemma 2, we also know that the ex-post decision bias of the lead investor exists precisely because she is not able to offer an *information-insensitive* security to the outside investor. In fact, the more information-sensitive the outside security $s(x)$ is, the higher the downward bias of θ^* is. Since straight debt is the least information-sensitive, its corresponding θ^* is the least downward biased (i.e. closest to θ^*_{ep}).

Lemma 4 *To implement a given level of downward bias, when $s(x)$ being straight debt, the smallest amount of inside funding is required (i.e. $I - F$ is lowest).*

Actually Lemma 4 is a dual problem of Lemma 3. The former tells us that for a given amount of outside finance, $s(x)$ being debt achieves the highest *ex-post* efficiency. The latter states that to achieve a certain level of efficiency $s(x)$ being debt requires the least amount of inside financing.

Further, by Myers and Majluf (1984), given the security type of outside financing, the more outside finance the firm uses, there is a higher possibility of inefficient pooling (i.e. the bad type of firm is more likely to be financed). Similarly,

Lemma 5 *Given the outside security type $s(x)$, say being straight debt, the bias is continuous and increasing with respect to F (i.e. $\theta^*_s(F)$ is decreasing in F).*

Proof: See the Appendix.

Now I am ready to present that the second-best can be implemented by the contract $(F, s(\tilde{x}))$ when outside security $s(\tilde{x})$ is straight debt.

Theorem 2 *If $s(\tilde{x})$ is straight debt, there is a unique financial contract in space $\{(F,\ s(\tilde{x}))\}$ to implement the second-best. That is, F is uniquely determined and it lies strictly in the interval $(0, L)$.*

Proof: see the appendix.

I denote the contract implementing the second best when $s(\tilde{x})$ is straight debt as $(F,\ s(\tilde{x})) \equiv (F_D, \min(\bar{K}, x))$.

Now I need to prove that $(F_D, \min(\bar{K}, x))$ is the optimal contract in the whole contact space $\{(F, s(\tilde{x}))\}$. That is, $s(\tilde{x})$ being straight debt is most appealing to the lead investor. Therefore, there is a unique optimal capital structure of the firm.

As I have shown, the lead investor's NPV in the second best is always V_{SB}. However, the required inside funding from the lead investor to achieve this same NPV is different for different outside security types. Hence the return is different for different outside security types. From Lemma 4, I have Lemma 6 immediately.

Lemma 6 *The lead investor obtains the highest return R_D when she chooses $s(x)$ to be straight debt, where $R_D = \frac{V_{SB}}{I-F_D}$.*

In the discussion so far, for simplicity, I ignore the participation constraint of the lead investor. In reality, it is quite normal in the private equity industry that the venture capitalist is constrained to participate because her reserve return of investment cannot be satisfied. The presence of the reserve return can be due to either a hurdle return demanded by the limited partners or a hurdle return required by the venture capitalist to exceed the opportunity cost of capital of alternative investments. Generally, after I take the lead investor's participation constraint of return into consideration, not all security types of $s(\tilde{x})$ are feasible. For example, if the lead investor's reserve return is $\bar{R}$, then the set of the feasible financial contracts that can implement the second best shrinks to $\{(F^*, s^*(\tilde{x}))\}$, where $F^* \geq I - \frac{V_{SB}}{\bar{R}}$.

My general point here is that because of the special nature of private equity investment (e.g. with limited financial resource to invest in multiple projects) the venture capitalist in reality cares about the return on the investment besides the NPV of a project. To put it simple, it is natural to assume that the venture capitalist chooses the project with the highest return for a given NPV.

Theorem 3 *If the lead investor prefers to have a higher return on investment for a given NPV, the only financial contract in space $\{C'\}$ that the lead investor chooses is $(F, s(x)) = (F_D, \min(\bar{K}, x))$. That is, the lead investor raises F_D amount of outside finance by choosing $s(x)$ as straight debt with face value $\bar{K}$.*

Importantly, if we take the payoff structure of outside security at T_1 as well as at T_2 into consideration, the outside security in my model is actually *long-term debt,* whose maturity is T_2. But if the firm is liquidated earlier at T_1, the outside investor has priority to claim the repayment F from the liquidation value. This result gives the rationale for using (long-term) debt in LBO investment.

4 Robustness of the model

4.1 *Renegotiation is impossible*

I consider renegotiation between the lead investor and management and between the lead investor and the outside investor in order.

4.1.1 *Between the lead investor and management*

As management derives a private benefit from continuing the project, there may exist some θ (below θ^*_{SB}) at which continuation is socially optimal (i.e. the private benefit plus the monetary payoff) while liquidation is the equilibrium in the second-best. In such cases, renegotiation is mutually beneficial to both the investor and management ex-post. However, because management is penniless and obtains zero monetary compensation from the project, he does not have any financial resources to bribe the investor into continuation incurring. Therefore, renegotiation like this case is impossible.

4.1.2 *Between the lead investor and the outside investor*

Renegotiation between the lead investor and the outside investor is impossible due to the information asymmetry. In fact, when $\theta \in [\theta^*_{SB}, \theta^*_{ep}]$ the lead investor inefficiently continues the unprofitable project in the second-best. There is scope for the lead investor and the outside investor to engage in mutually beneficial renegotiation *ex-post* at T_1. However, due to asymmetric information between the two parties (i.e. the outside investor cannot observe θ), the only possibility for mutually beneficial renegotiation is that the lead investor initializes the proposal for a new contract after she observes $\theta \in [\theta^*_{SB}, \theta^*_{ep}]$.[26] The new contract provides to liquidate the project for sure but the outside investor needs to reduce his claim in the liquidation value.[27] However, the lead investor can provide the same proposal when $\theta < \theta^*_{SB}$ in which she does not decide to continue the project anyway even under the original contract and thus the new contract is only beneficial to the lead

[26] In fact, this is a signaling game.

[27] Without loss of generality, I assume that the lead investor has full bargain power.

investor while making the outside investor worse off. Therefore, the outside investor will not 'trust' the lead investor. Hence, the renegotiation in this case will not happen either. The second-best equilibrium is sustained.

4.2 *Monetary compensation for management is insufficient*

In this subsection I am going to prove that the monetary compensation scheme for management is insufficient. That is, the monetary compensation scheme cannot solve the commitment problem we discussed above. This is the reason why I could abstract from monetary compensation by normalizing it to zero so far.

I provide the intuition first. Suppose management cares about the monetary payoff as well as the private benefit. His ex-ante effort depends on his expectation on these two kinds of payoffs. Thus, there are also two ways for the investor to incentivize management to exert effort: pay management a monetary compensation and give management her commitment to continue the project. The latter concerns the second type of management's preference — the private benefit. Note that both of the above two incentives are costly to the investor. It is obvious that monetary compensation is costly. The commitment is costly because some unprofitable project will be continued under the commitment. In order to incentivize management to exert a certain level of effort, I argue that the optimal compensation policy should be a mix of monetary compensation and commitment. It is never optimal for the investor to use just one incentive. In particular, monetary compensation alone is too costly relative to a mix of monetary compensation and commitment to achieve a certain level of effort. That is, the commitment is always necessary for minimizing the investor's cost and maximizing her wealth. In order to highlight and concentrate on the effect of commitment instead of monetary compensation on effort, I have disregarded the monetary compensation and assumed management does not care about money or that the monetary payoff is negligible compared to the private benefit.

Now let us move to the mathematical proof. I consider all possible monetary compensation schemes for management. Note that our assumption is that the 'Failure' and the 'Success' states are uncontractable. The only contractable variable is the 'continuation' and 'liquidation' decision. Therefore, the available compensation schemes for management can be expressed in the form of (n,

$m(x))$, where n (≥ 0) is a constant salary in case of 'Liquidation' and $m(x)$ is the compensation in case of 'Continuation'. Under such compensation, management's utility can be rewritten as $U(e) = [(1-e)+e(1-p)]\cdot n + e\cdot \int_{\theta=\theta^*}^{\theta=1} \{B + E[m(\tilde{x})|\theta]\}\cdot g(\theta)d\theta - \Psi(e)$. By the first order condition $U'(e) = 0$, I have $\int_{\theta=\theta^*}^{\theta=1} \{(B-n) + E[m(\tilde{x})|\theta]\}\cdot g(\theta)d\theta = \Psi'(e)$ (IC) (12)

From (12), we obtain that e is a decreasing function of n, that is, the higher management's salary in case of 'liquidation', the lower the effort management exerts. From the perspective of the investor, it is also costly for her to pay management the compensation n. Considering that the investor prefers management to exert high effort, n must therefore be 0 in the optimal compensation. Intuitively, in order to incentivize management to exert effort, it is optimal to the investor to increase the difference in compensation in 'liquidation' and 'continuation'. The highest difference occurs when $n = 0$.

When the firm is fully inside financing, under the compensation scheme $(n = 0, m(x))$, the investor's utility is

$$V(\theta^*) = -I + (1-e)(L-n) + e\cdot\{(1-p)(L-n) + \int_{\theta=\theta^*}^{\theta=1} E[\tilde{x} - m(\tilde{x})|\theta]\cdot g(\theta)d\theta\}$$

$$= -(I-L) + e\cdot \int_{\theta=\theta^*}^{\theta=1} \{E[\tilde{x} - m(\tilde{x})|\theta] - L\}\cdot g(\theta)d\theta \qquad (13)$$

Ex-post, the investor chooses θ^* as $\theta^*_{ep} = \min\{\theta|\ E[\tilde{x} - m(\tilde{x})|\theta] \geq L\}$. Again, I can prove that the investor's utility $V(\theta^*)$ will increase if θ^* decreases a bit by using outside financing. In fact,

$$\frac{\partial V}{\partial \theta^*}|_{\theta^*=\theta^*_{ep}} = \underbrace{\frac{\partial e}{\partial \theta^*}}_{<0} \underbrace{\int_{\theta=\theta^*}^{\theta=1} \{E[\tilde{x} - m(\tilde{x})|\theta] - L\}\cdot g(\theta)d\theta}_{>0} - \underbrace{\{E[\tilde{x} - m(\tilde{x})|\theta^*] - L\}\cdot g(\theta^*)\cdot e}_{=0}$$
$$< 0.$$

Therefore, outside financing is useful and necessary in order to maximize the investor's utility.

Nevertheless, when the investor pays monetary compensation to management, there is scope for the investor and management to renegotiate at T_1. Without loss of generality, I assume that the investor has all the bargaining power. Without renegotiation, the investor chooses θ^* as $\theta^*_{ep} = \min\{\theta|\ E[\tilde{x} - m(\tilde{x})|\theta] \geq L\}$. Obviously, the investor inefficiently liquidates the project too often. Renegotiation can achieve ex-post efficiency by pushing θ^* down to $\min\{\theta|\ E[\tilde{x}|\theta] \geq L\}$. In fact, when $\theta \in [\min\{\theta|\ E[\tilde{x} - m(\tilde{x})|\theta] \geq L\}, \min\{\theta|\ E[\tilde{x}|\theta] \geq L\}]$, renegotiation results in the project being continued while the investor pays zero monetary compensation to management under such continuation. This renegotiation makes both parties better off relative to no renegotiation. The above problem is equivalent to the debt-overhang problem, where 'debt' is $m(\bar{x})$.

After taking renegotiation into account, the problem is the same as the one we were studying in Section I, where θ^* is also $\theta^*_{ep} = \min\{\theta|\ E[\tilde{x}|\theta] \geq L\}$. Clearly, on the basis of monetary compensation $(n,\ m(x))$, outside financing can reduce θ^* further and make θ^* fall below θ^*_{ep} to implement the second-best. Therefore, outside financing is necessary even if I take monetary compensation and renegotiation into account.

Finally, I want to point out that the assumption that the 'Failure' and the 'Success' states are uncontractable is not necessary for me to derive the result in this section — monetary compensation is insufficient. I can show that even if the states are contractable, monetary compensation still cannot solve the commitment problem. Outside financing, which can realize the commitment, is still necessary. As this argument is not necessary for the paper, I omit its mathematical proof.

5 Conclusion

In this paper, I model the capital structure of private equity-backed firms and propose a novel rationale for using outside financing in private equity investment. The theoretical framework in this paper provides new explanations for several stylized facts. These facts include that outside security in buyouts is typically debt and the maturity is usually long-term. I cannot deny, however, the multiple motivations for the use of outside financing in reality. My theory, which provides a new perspective to explain the role of outside financing, can be seen as complementary to the existing theories.

The firms backed by the private equity fund distinguish themselves from the public firms through two key features: the highly-concentrated ownership and the finite life of the investors. (Note: partnership agreements typically require the fund to be finitely-lived (Sahlman (1990)). The combination of these two features gives rise to some special implications for the corporate governance of such kinds of firms. It is well recognized in the finance literature (e.g. Shleifer and Vishny (1986, 1997)) that concentrated ownership facilitates ownership to excise control. Simultaneously, the finite life of investors implies that the exit or continuation/liquidation is one of the most important control decisions in private equity investment. Therefore, the combined nature of concentrated ownership and the finite life of investors suggest that the investor (i.e. the venture capitalist) has both the *capability* and the *incentive* to take tight (ex-post) control of continuation/liquidation.

However, tight ex-post control may disincentivize ex-ante effort provision by management. This is particularly true for private equity investment, which is characterized by high external risk besides internal risk, and high private benefits (for management) besides his monetary utility. The presence of these characteristics makes the incentive problem in private equity investments particularly severe. Furthermore, under these features, I show that monetary performance-based compensation is not sufficient to mitigate the incentive problem. Using outside financing and thus loosing ex-post control, which can in turn provide *indirect* ex-ante incentive, is always necessary in addition to the *direct* incentive mechanism like monetary performance-based compensation. It has been well known both in academic and practice that high management incentive pay is an important governance mechanism in private-equity backed firm. In the paper, however, I argue that high leverage of capital structure – another distinguishing aspect of private-equity backed firms – is also an important incentive device in private-equity backed firms.

Appendix: *Extension – more general contract space*

In the discussion of text, in order to simplify the analysis and highlight the main intuition of the model, I limit the contract space to $\{(F, s(x))\}$, that is, if the firm is liquidated earlier at T_1, the outside investor has priority to claim his original investment F from the liquidation value. In this subsection I consider the more general contract space. The main result of the model doesn't change.

First of all, I consider the most common case that outside security is the *standard* long-term debt. Under the new assumption, the conclusion that there exists a unique implementation of the second-best keeps unchanged. The contract when outside security being standard long-term debt can be defined as $(F, K, \min(K, x))$: the outside investor invests F at T_0, obtain the face value K in the case of early liquidation at T_1, and claims straight debt payoff $\min(K, x)$ at T_2 in the case of continuation. The face values at T_1 and at T_2 are same (both K). Under the contract $(F, K, \min(K, x))$, the lead investor's θ^* decision is governed by

$$\begin{cases} \theta^* = \min\{\theta | E[\tilde{x} - \min(K, \tilde{x})|\theta] \geq L - K\} & \text{(the lead investor's rational choice)} \\ -F + (1-e)K + e\{\int\limits_{\theta=0}^{\theta=\theta^*} K \cdot g(\theta)d\theta + \int\limits_{\theta=\theta^*}^{\theta=1} E[\min(K, \tilde{x})|\theta] \cdot g(\theta)d\theta\} = 0 & \text{(IR of the outside investor)} \end{cases}$$

I have the following result.

Theorem 4 *Under the contract $(F, K, \min(K, x))$, the lead investor's decision bias is continuous and increasing with respect to F (i.e. θ^* is decreasing in F). There exists a unique amount of outside financing F implementing the second-best.*

Proof: see the appendix.

Secondly, I consider the more general mechanism design where there is no exogenous limitation to the amount of repayment to the outside investor in the case of early liquidation. Specifically, I define contract space $\{(F, A, s(x))\}$, that is, the outside investor invests F at T_0, obtains the repayment with a fixed amount A in the case of liquidation, and claims $s(x)$ in continuation. In this case, the lead investor's θ^* decision is determined by the following joint equations:

$$\begin{cases} \theta^* = \min\{\theta | E[\tilde{x} - s(\tilde{x})|\theta] \geq L - A\} & \text{(the lead investor's rational choice)} \\ -F + (1-e)A + e\{\int_{\theta=0}^{\theta=\theta^*} A \cdot g(\theta)d\theta + \int_{\theta=\theta^*}^{\theta=1} E[s(\tilde{x})|\theta] \cdot g(\theta)d\theta\} = 0 & \text{(IR of the outside investor)} \end{cases}$$

Under the new contract, if the outside investor has priority to claim at least his original investment F from the liquidation value in the case of early liquidation (i.e. $A \geq F$), I show the optimal contract is still the one in Theorem 3. That is, it is never optimal for the lead investor to repay more than the outside investor's original investment F at T_1. Otherwise the lead investor cannot realize the highest return. This is Theorem 5.

Theorem 5 *If the lead investor prefers to have a higher return on investment for a given NPV, the only financial contract in space* $\{(F, A, s(x))|A \geq F\}$ *that the lead investor chooses is* $(F, A, s(x)) = (F_D, F_D, \min(\bar{K}, x))$.

Proof: see the appendix.

However, if there is no restrication of $A \geq F$, the optimal contract typically needs to set A lower than F. This helps the lead investor realize the highest return.

Theorem 6 *If the lead investor prefers to have a higher return on investment for a given NPV, in the optimal financial contract of space* $\{(F, A, s(x))\}$*, A's value is between* 0 *and* F.

Appendix: proof

Proof of Theorem 1: I only need to prove that the manager's utility under the fully-inside-financing is less than that under the second-best. Since $\theta^*_{SB} < \theta^*_{ep}$, I have $a^*_{SB} > a^*_{ep}$ where a^*_{ep} is the manager's effort in the fully-inside-financing. Therefore, $U(a^*_{SB}) = [a^*_{SB} \cdot \int_{\theta=\theta^*_{SB}}^{\theta=1} g(\theta)d\theta] - \Psi(a^*_{SB})$ $\geq [\theta^*_{ep} \cdot \int_{\theta=\theta^*_{SB}}^{\theta=1} g(\theta)d\theta] - \Psi(\theta^*_{ep}) > [\theta^*_{ep} \cdot \int_{\theta=\theta^*_{ep}}^{\theta=1} g(\theta)d\theta] - \Psi(\theta^*_{ep})$. Q.E.D.

Proof of Lemma 5: The continuity is trivial since all the functions involved are regular and continuous. To prove monotonicity, I need to show that if $F_{new} < F_{old}$, then $\theta^*_{new} > \theta^*_{old}$, where θ^*_{new} and θ^*_{old} denote $\theta^*(F_{new})$ and $\theta^*(F_{old})$ respectively.

From (11), I have $\int_{\theta=\theta^*_{old}}^{\theta=1} \{E[(\min(\tilde{x}, K_{old})|\theta]-F_{old}\}\cdot g(\theta)d\theta = 0$ and $\int_{\theta=\theta^*_{new}}^{\theta=1} \{E[(\min(\tilde{x}, K_{new})|\theta]-F_{new}\}\cdot g(\theta)d\theta = 0$. Hence, $\int_{\theta=\theta^*_{old}}^{\theta=\theta^*_{new}} \{E[(\min(\tilde{x}, K_{old})|\theta]-F_{old}\}\cdot g(\theta)d\theta + \int_{\theta=\theta^*_{new}}^{\theta=1} \{E[(\min(\tilde{x}, K_{old})|\theta]-F_{old}\}\cdot g(\theta)d\theta - \int_{\theta=\theta^*_{new}}^{\theta=1} \{E[(\min(\tilde{x}, K_{new})|\theta]-F_{new}\}\cdot g(\theta)d\theta = 0$

Rewrite the above equation, I obtain,

$\int_{\theta=\theta^*_{old}}^{\theta=\theta^*_{new}} \{E[(\min(\tilde{x}, K_{old})|\theta]-F_{old}\}\cdot g(\theta)d\theta + \int_{\theta=\theta^*_{new}}^{\theta=1} \{E[\min(\tilde{x}, K_{old})-\min(\tilde{x}, K_{new})|\theta]-(F_{old}-F_{new})\}\cdot g(\theta)d\theta = 0$ (14)

Clearly, from $F_{new} < F_{old}$, I have $K_{old} > K_{new}$. Thus $\min(\tilde{x}, K_{old})-\min(\tilde{x}, K_{new})$ is an increasing function as $x \in [0, \bar{X}]$. Therefore, $E[\min(\tilde{x}, K_{old})-\min(\tilde{x}, K_{new})|\theta]$ is increasing of θ. As $\theta^*_{new} \to \theta^*_{old}$, the first term in (14) approaches 0 and the second-term approaches $\int_{\theta=\theta^*_{old}}^{\theta=1} \{E[\min(\tilde{x}, K_{old})-\min(\tilde{x}, K_{new})|\theta]-(F_{old}-F_{new})\}\cdot g(\theta)d\theta$. Thus I get $\int_{\theta=\theta^*_{old}}^{\theta=1} \{E[\min(\tilde{x}, K_{old})-\min(\tilde{x}, K_{new})|\theta]-(F_{old}-F_{new})\}\cdot g(\theta)d\theta = 0$, which means $E[\min(\tilde{x}, K_{old})-\min(\tilde{x}, K_{new})|\theta^*_{old}] < F_{old}-F_{new}$.

By (10), I know $E[(\max(0, \tilde{x}-K_{new})|\theta^*_{new}] = L-F_{new}$. But $E[(\max(0, \tilde{x}-K_{new})|\theta^*_{old}]=E[(\max(0, \tilde{x}-K_{old})|\theta^*_{old}]-E[\max(0, \tilde{x}-K_{old})-\max(0, \tilde{x}-K_{new})|\theta^*_{old}] = (L-F_{old})+E[\min(\tilde{x}, K_{old})-\min(\tilde{x}, K_{new})|\theta^*_{old}] < (L-F_{old})+(F_{old}-F_{new}) = L-F_{new}$.

Therefore, $\theta^*_{new} > \theta^*_{old}$. Q.E.D.

Proof of Theorem 2: First of all, let us consider the investor's choose of θ when $F = 0$. In this case, the firm is fully inside financing. The investor's criterion to choose θ^* becomes $\theta^*(0) = \min\{\theta|E(\tilde{x}|\theta) \geq L\}=\theta^*_{ep}$. By $\theta^*_{ep} > \theta^*_{SB}$, I get $\theta^*(0) > \theta^*_{SB}$.

Secondly, let us consider the other extreme case: $F = L$. In this case, the investor's criterion to choose θ^* is $\theta^*(L) = \min\{\theta|E[\tilde{x}-s(\tilde{x})|\theta] \geq 0\}$ subject to $\int_{\theta=\theta^*(L)}^{\theta=1} \{E[s(\tilde{x})|\theta]-L\}\cdot g(\theta)d\theta = 0$. By the assumption $\int_{\theta=0}^{\theta=1} E(\tilde{x}|\theta)\cdot g(\theta)d\theta \leq L$, $\theta^*(L)$ is implicitly determined by $\int_{\theta=\theta^*(L)}^{\theta=1} [E(\tilde{x}|\theta)-L]\cdot g(\theta)d\theta = 0$.

Now I need to prove $\theta^*(L) < \theta^*_{SB}$. If I evaluate the first-order derivative of utility function at $\theta^* = \theta^*(L)$, I get

$$\frac{\partial V}{\partial\theta^*}|_{\theta^*=\theta^*(L)} = \underbrace{\frac{\partial a}{\partial\theta^*}}_{<0} \underbrace{\int_{\theta=\theta^*}^{\theta=1} [E(\bar{x}|\theta) - L] \cdot g(\theta) d\theta}_{=0} - \underbrace{(E(\bar{x}|\theta^*) - L) \cdot g(\theta^*) \cdot e}_{<0}$$

> 0,

which means $\theta^*_{SB} > \theta^*(L)$ considering $\frac{\partial V}{\partial\theta^*}|_{\theta=\theta^*_{SB}} = 0$.

Combining the above two cases, I obtain $\theta^*(0) > \theta^*_{SB} > \theta^*(L)$, that is, θ^*_{SB} lies within the range $(\theta^*(L), \theta^*(0))$.

Moreover, as $\theta^*(F)$ is continuous and decreasing of F, there is a unique F^{SB} such that $\theta^*(F^{SB}) = \theta^*_{SB}$. F^{SB} is the optimal amount of outside funding. Q.E.D.

Proof Theorem 4: The proof is similar with that of Theorem 2. In fact, in the following equation system:

$$\begin{cases} \theta^* = \min\{\theta | E[\tilde{x} - \min(K, \tilde{x})|\theta] \geq L - K\} & \text{(the lead investor's rational choice)} \\ -F + (1-e)K + e\{\int_{\theta=0}^{\theta=\theta^*} K \cdot g(\theta)d\theta + \int_{\theta=\theta^*}^{\theta=1} E[\min(K, \tilde{x})|\theta] \cdot g(\theta)d\theta\} = 0 & \text{(IR of the outside investor)} \end{cases}$$

fixing θ^* as θ^*_{SB}, there are only two unknowns (K,F) while there are two equations. The equation system has at most one solution (i.e. both K and F are unique determined by θ^*_{SB}). We only need to prove there do exsit solutions for the equations system. This is obvious and it is similar with Theorem 2. In fact, if $F = 0$ (i.e. the firm is fully inside financing), then $K = 0$ and $\theta^* = \theta^*_{ep}$. If $F = L$ (i.e. the firm uses too much outside financing), then $\theta^* = 0$. Also considering θ^* is a continuous function of F, the equations system has at least one solution.

Proof of Theorem 5: I can rewrite the equations system

$$\begin{cases} \theta^* = \min\{\theta | E[\tilde{x} - s(\tilde{x})|\theta] \geq L - A\} & \text{(the lead investor's rational choice)} \\ -F + (1-e)A + e\{\int_{\theta=0}^{\theta=\theta^*} A \cdot g(\theta)d\theta + \int_{\theta=\theta^*}^{\theta=1} E[s(\tilde{x})|\theta] \cdot g(\theta)d\theta\} = 0 & \text{(IR of the outside investor)} \end{cases}$$

as

$$\begin{cases} \theta^* = \min\{\theta | E[\tilde{x} - s(\tilde{x})|\theta] \geq L - A\} & \text{(the lead investor's rational choice)} \\ e\int_{\theta=\theta^*}^{\theta=1} (E[s(\tilde{x})|\theta] - A) \cdot g(\theta)d\theta = F - A & \text{(IR of the outside investor)} \end{cases}$$

Under $\{(F, A, s(x))|A \geq F\}$, the right hand side of second equation is (weak) negative, which means that the θ^* is more downward biased under $\{(F, A, s(x))|A \geq F\}$ than under $\{(F, s(\tilde{x}))\}$ for a same F. Therefore, to implement a certain level of downward bias, $\{(F, A, s(x))|A \geq F\}$ requires less outside finance and thus the return is lower. The optimal contract realizing the highest return should be the one that specifies $A = F$.

References

[1] Aghion, Phillipe and Patrick Bolton, 1992, An incomplete contracts approach to financial contracting, *Review of Economics Studies*, 59, 473-496.

[2] Aghion, Phillipe and J. Tirole, 1997, Formal and Real Authority in Organizations, *Journal of Political Economy*, 105, 1-29.

[3] Axelson, Ulf, Per Stromberg and Michael Weisbach, 2005, The Financial Structure of Private Equity Funds, Working paper, University of Illinois.

[4] Burkart, Mike, Denis Gromb and Fausto Panunzi, 1997, Large Shareholders, monitoring, and the value of the firm, *Quarterly Journal of Economics*, 112, 693-728.

[5] Bygrave, William, 1987, Syndicated investments by venture capital rms : a networking perspective,Journal fo Business Venturing 2, 139-154.

[6] Bygrave, William, 1988, The structure of the investment networks of venture capital rms, Journal fo Business Venturing 3,137-157.

[7] Dewatripont, M. and Maskin, E.,1995, Credit and Efficiency in Centralized and Decentralized Economies, *Review of Economic Studies,* 62(4), 541-555.

[8] Dewatripont, Mathias and Jean Tirole, 1994, A theory of debt and equity: diversity of securities and manager-shareholder congruence, *Quarterly Journal of Economics*, 109, 1027-1054.

[9] Diamond, D., 1991, Debt maturity structure and liquidity risk, *Quarterly Journal of Economics*, 106, 709-737.

[10] Fenn, George, Nellie Liang, and Steven Prowse, "The Private Equity Industry: An Overview," (Financial Markets, Institutions and Instruments Series, Volume 6, Number 4), Boston, Blackwell Publishers, 1997.

[11] Fluck, Z., K. Garrison, and S. Myers, 2005, Venture Capital Contracting and Syndication: An Experiment in Computational Corporate Finance, NBER Working Paper No. 11624, Boston.

[12] Gompers, Paul and Josh Lerner, 1996, The use of covenants: An empirical analysis of venture partnership agreements, *Journal of Law and Economics* 39.

[13] Grossman, S. and Hart, O. 1986, The cost and the benefits of investorship: a theory of vertical and lateral integration, *Journal of Political Economy*, 691-719.

[14] Hart, O., 1995, Firms, contracts and financial structure, Clarendon Press, Oxford.

[15] Hart, O. and John Moore, 1990, Property rights and the nature of the firm, Journal of Political Economy, 1119-1158.

[16] Holmstrom, Bengt, 1979, Moral hazard and observability, *Bell Journal of Economics*,10, 74–91.

[17] Inderst and Müller, 2004, Capital structure and credit decisions, Mimeo, New York University.

[18] Inderst and Mueller, 2006, Informed lending and security design, *Journal of Finance*, forthcoming.

[19] Innes, 1990, Limited liability and incentive contracting with ex-ante action choices, *Journal of Economic Theory*, 52, 45-67.

[20] Jensen, Michael C., 1986, Agency costs of free cash flow, corporate finance, and takeovers, *American Economics Review*, 76, 323-329.

[21] Lerner, Josh, 1994, The Syndication of Venture Capital Investments, Financial Management, 23, 16-27.

[22] Lerner, Josh, 1998, Venture Capital and Private Equity: A Course Overview, Available at SSRN: http://ssrn.com/abstract=79148.

[23] Liu, Xuewen, 2006, Stage Financing and Syndication in Venture Capital Investment, working paper, LSE.

[24] Liu, Xuewen, 2006, Managerial Incentive, Ownership Control and External Finance: A Theory of Capital Structure, available at SSRN: http://ssrn.com/abstract=894364

[25] Kaplan, Steven and A. Schoar, 2005, Private equity performance: Returns, persistence, and. capital flows, *Journal of Finance*, forthcoming.

[26] Kaplan, Steven and Jeremy Stein, 1993, The evolution of buyout pricing and nancial structure in the 1980s, *Quarterly Journal of Economics*, 27, 215-246.

[27] Kaplan, Steven and Per Strömberg, 2004, Characteristics, Contracts, and Actions: Evidence from Venture Capitalist Analyses, *Journal of Finance*, 59(5), 2177-2210.

[28] Myers, Stewart C. and N. Majluf, 1984, Corporate financing and investment decisions when firms have information that investors do not have, *Journal of Financial Economics*, 13, 187-222.

[29] Prendergast, C. 2002, The Tenuous Trade-off between Risk and Incentives, *Journal of Political Economy*, 110, 1071-1102.

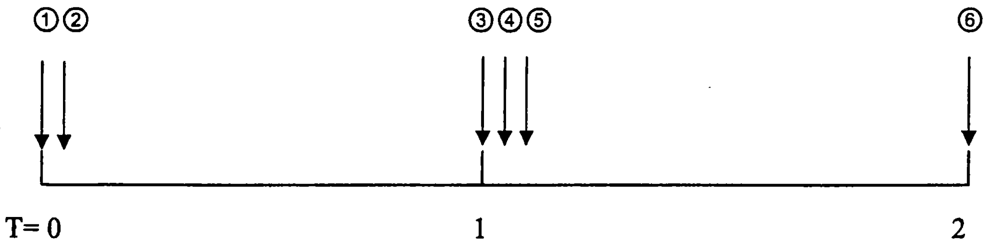
[30] Sahlman, W.A., 1990, The Structure and Governance of Venture Capital Organizations, *Journal of Financial Economics*, 27, 473-521.

[31] Shleifer, Andrei and Robert Vishny, 1986, Large Shareholders and Corporate Control, *Journal of Political Economy*, XCIV, 461–88.

[32] Shleifer, Andrei and Robert W. Vishny, 1997, A survey of corporate governance, *Journal of Finance,* 52, 737-83.

[33] Stulz, R.,1990, Managerial Discretion and Optimal Financing Policies, *Journal of Financial Economics*, 26, 3-27.

Figure 1: The timeline



① The investment takes place.

② Management exerts his effort.

③ The investor and management observe the state. If 'Success' state happens, they also receive the signal.

④ The investor makes the continuation/liquidation decision.

⑤ If case of liquidation, the liquidation value is realized.

⑥ In case of continuation, the final payoff is realized.

Figure 2: The tradeoff between incentive and control

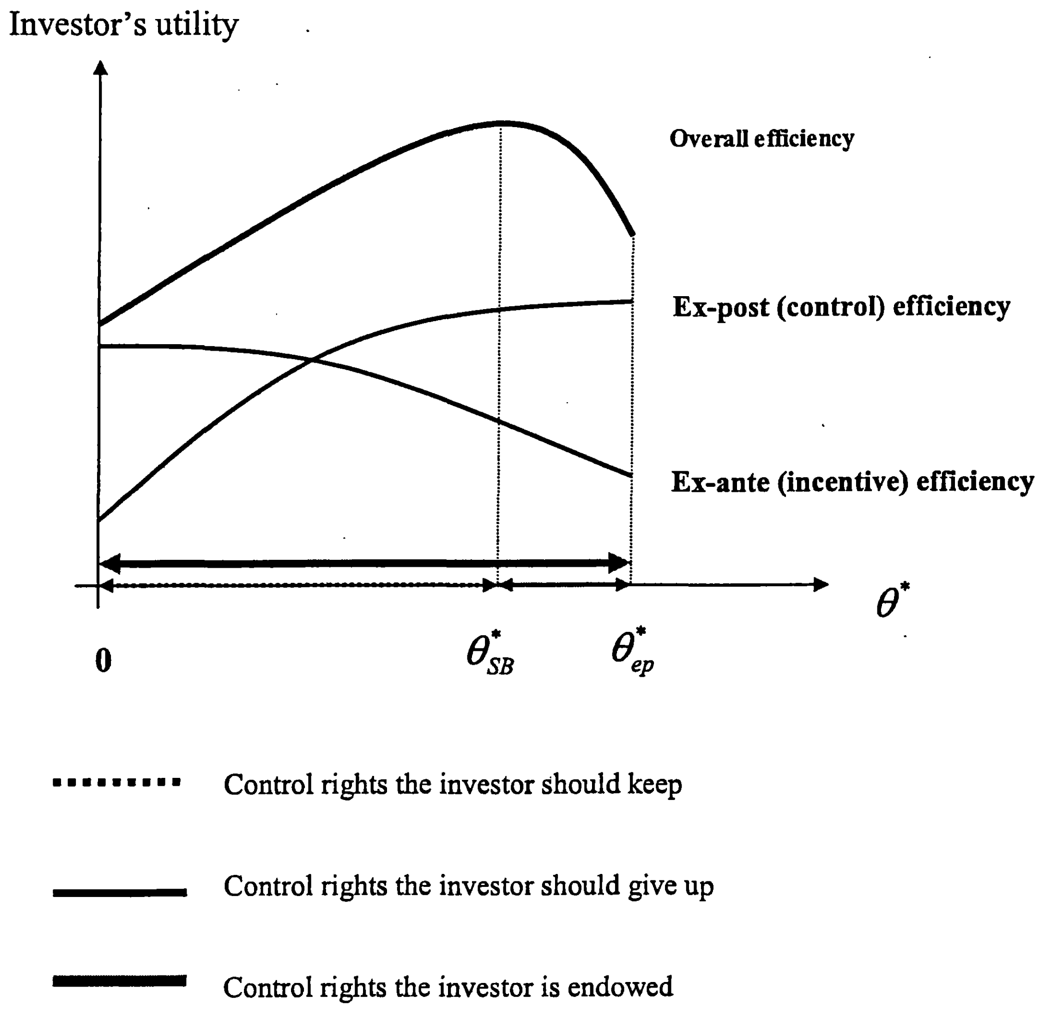
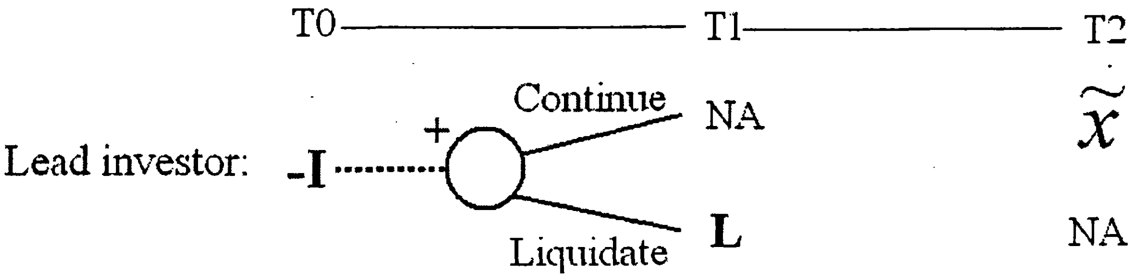
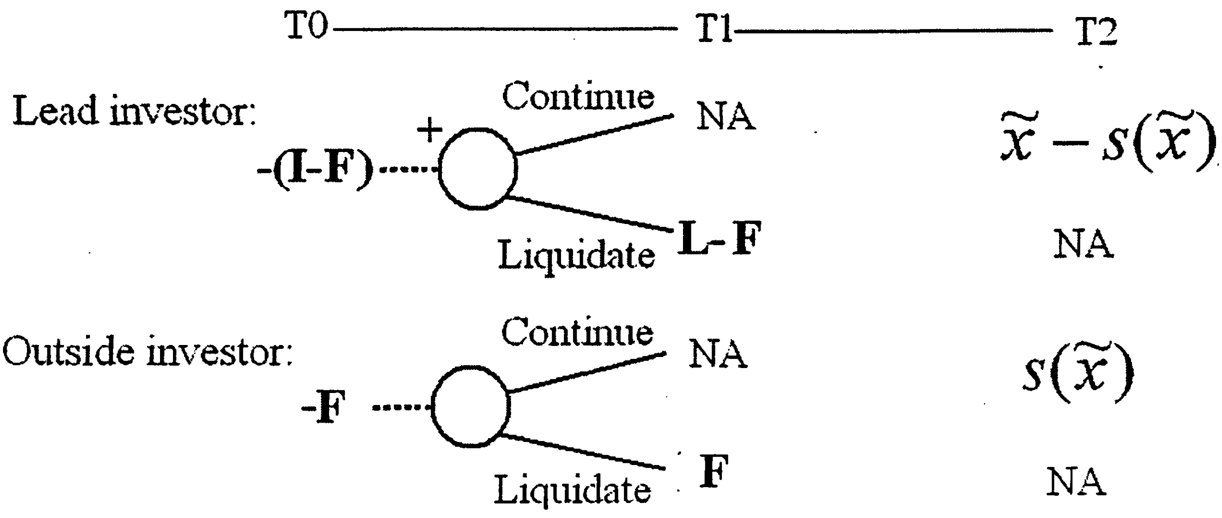


Figure 3: The cash flow and decision rights allocation across agents

Without outside finance



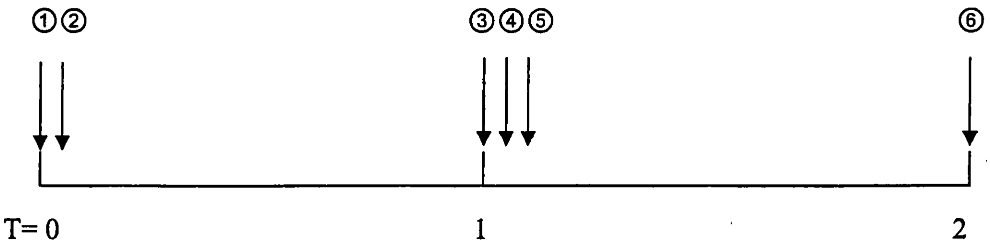
With outside finance under financial contract C'



\+ : **Decision right of continuation/liquidation**

NA: **Not applicable**

Figure 4: The timeline with outside financing



① The investor **decides the financial structure** and the investment takes place.

② Management exerts the effort.

③ The investor and management observe the state. If 'Success' state happens, they also receive the signal.

④ The investor makes the continuation/liquidation decision.

⑤ In case of liquidation, **the liquidation value is distributed.**

⑥ In case of continuation, the final payoff is realized and **distributed.**

DOI: 10.1111/j.1475-679X.2007.00231.x
Journal of Accounting Research
Vol. 45 No. 2 May 2007
Printed in U.S.A.

Market Transparency and the Accounting Regime

ALEXANDER BLECK* AND XUEWEN LIU*

Received 9 January 2006; accepted 17 November 2006

ABSTRACT

We model the interaction of financial market transparency and different accounting regimes. This paper provides a theoretical rationale for the recently proposed shift in accounting standards from historic cost accounting to marking to market. The paper shows that marking to market can provide investors with an early warning mechanism while historical cost gives management a "veil" under which they can potentially mask a firm's true economic performance. The model provides new explanations for several empirical findings and has some novel implications. We show that greater opacity in financial markets leads to more frequent and more severe crashes in asset prices (under a historic-cost-accounting regime). Moreover, our model indicates that historic cost accounting can make the financial market more rather than less volatile, which runs counter to conventional wisdom. The mechanism shown in the model also sheds light on the cause of many financial scandals in recent years.

1. *Introduction*

Market transparency is generally believed to be a key mechanism that reduces the information asymmetry among market participants thereby guaranteeing market efficiency. In fact, the opacity of markets was blamed for

*London School of Economics. We are grateful to Hyun Song Shin and Thomas Hemmer for their guidance and continued support, the editor Ray Ball and one anonymous referee for detailed comments, and David Webb, Dimitri Vayanos, and seminar participants at LSE for helpful discussions. Both authors are PhD students in finance at LSE. Communications to: Department of Accounting and Finance, LSE, London WC2A 2AE, UK; a.bleck@lse.ac.uk, x.liu@lse.ac.uk.

the cause of many recent scandals such as Enron, Worldcom, and Fannie Mae. In cases like these, investors and regulators often discover pertinent information too late to be able to take measures to prevent a potential crisis from happening. The *Sarbanes-Oxley Act* of 2002 may be seen as a direct response of regulators to such criticism. Moreover, as a central piece of the infrastructure of financial markets aimed at enhancing market transparency, accounting standards have become a key area of proposed reform over the last couple of years. One such proposal and central issue of the debate is the shift of the accounting regime from historic cost (HC) accounting to marking to market (MTM) with the objective of improving market transparency.

However, there are many voices against such a reform. The main reason for the objections focuses on the infeasibility of implementing the marking-to-market regime. That is, the so-called "fair value" is seldom available in reality. Ideally, if the true value of an asset or liability could be observed, we would use this as the accounting measure. Marking to market would then lead to first-best efficiency. In reality, however, market frictions prevent us from determining a fair value. Most markets are too illiquid to allow for timely and accurate valuation. The debate does not put into question whether marking to market *itself* is optimal. The issue is rather whether it is possible to implement such a regime. That is, the center of the debate is the *feasibility* of marking to market, not its *validity*. Plantin, Sapra, and Shin [2004, p. 2] (hereafter, PSS) write

> [...] a rapid shift to a full mark-to-market regime may be detrimental [...]. This is not to deny that such a transition is a desirable long-run aim. In the long run, large mispricings in relatively illiquid secondary markets would likely trigger financial innovations in order to attract new classes of investors. This enlarged participation would in turn enhance liquidity, a situation in which our analysis shows that marking to market becomes more efficient.

The difficulty or infeasibility of *fully* implementing a marking-to-market scheme makes a mixed compromise unavoidable, whereby some items are recorded at historic cost while others are marked to market. The decision by the European Commission last November to endorse a mixed reporting scheme[1] is evidence of a similar thought process. The prerequisite for finding an *optimal* compromise, however, is to understand the advantages and disadvantages of different accounting regimes and their effects on market transparency. While understanding that the main difficulty of marking to market lies in its *infeasibility*, both academics and practitioners are not yet very clear about what the problems of historic cost accounting and the mechanisms are by which these problems are produced. The main motivation for this paper is to investigate these problems and their mechanisms.

In studying the accounting regimes and their economic implications, the first natural question to ask is what the difference between the accounting

[1] "A Question of Measurement," *The Economist*, October 23, 2004, p. 83.

regimes is and why the shift from one regime to another matters. In fact, although the proposal to shift the accounting regime to MTM is a recent one, various forms of MTM accounting have already been practiced for centuries, particularly in the form of the so-called lower-of-cost-or-market (LCM) rule.

However, the implementation of the conservative principle like LCM, which is a "rule" rather than a "law," depends on several factors: industry, market, and country. First, LCM is seldom used in the financial industry, which has been a particular target of accounting regulation in recent years. Even in the manufacturing industry, the LCM rule is not applicable to long-term, illiquid assets. For other assets, LCM is not implemented with high frequency (e.g., only seasonally or annually). In the interim, it is still pure HC accounting that is used. Second, a liquid market is necessary for the implementation of LCM, a rare situation in reality. In fact, the lack of liquidity is the very source of difficulty of implementing MTM in the first place. Third, as Ball, Robin, and Sadka [2005] show, the conservative accounting practice varies across countries. In many countries, it is hard to strictly implement LCM. In order to highlight and study the difference between MTM and HC accounting, HC accounting in this paper is interpreted as HC accounting in the strict sense (i.e., without the LCM element).[2]

The main insight of this paper is that marking to market can provide investors with an early warning mechanism while historical cost gives the manager a "veil" to potentially mask the firm's true performance. That is, historical cost accounting is equivalent to granting a free call option to the manager. If the firm's performance is good (i.e., its market price is high), the manager can choose to sell, making the book value reflect the asset's market price. On the contrary, if the asset's market value is low, he can hold the asset and report a book value equal to the asset's initial cost. Hence, however low the market value is, the manager has a "floor" in the book value—the project's initial cost. At the same time, he can fully benefit from the project's upside. This "convexity" in the book value is the typical feature of a call option. In practice, as accounting-value-based compensation, such as profit-based bonuses, is widely used, the manager has an incentive to maximize the accounting numbers. Hence he has an incentive to use his free option. We will essentially show that historic cost accounting will not only "incentivize" but also "enable" the manager to mask the firm's true performance. The manager has an incentive because he would like to keep

[2] In fact, even if we don't interpret HC accounting as its pure form, HC accounting with LCM still differs from MTM; they have quite different economic consequences. HC accounting with LCM can only reveal a decrease and not an increase in the asset value (conservative principle). Specifically, a company (and its investors) may well consider a project that earns a low positive return a failure. The investors may want it liquidated and have the resources redeployed. However, under HC accounting with LCM, the investors cannot distinguish a low positive return from a very high positive return. Hence they cannot tell that the asset is earning a substandard return. With MTM accounting, they would be able to. In other words, even if LCM is applied stringently, it provides managers a veil in some cases whereas MTM never does.

a bad project "alive" in order to secure the convex payoff next period. He is also able to because he can hide the project's poor performance by setting the book value equal to the asset's initial cost.

Our main findings are two. First, our model implies a relationship between market transparency and asset price crashes under historic cost accounting. Myers and Jin [2004] document that countries where firms are more opaque to outside investors have a higher frequency of crashes in asset prices. Our model can provide an explanation for such evidence. The idea is as follows: In a more transparent market, the shareholder is able to distinguish good from bad projects and hence achieve a first-best outcome by liquidating poor projects. However, in more opaque financial markets, the shareholder may have to let a poor project continue as the manager can use historic cost accounting to pool good with bad projects. Failure of the shareholder to discriminate good from bad projects at an early stage allows bad projects to be kept alive and to potentially worsen in quality over time. The poor performance of these projects can thus accumulate and only eventually materialize at their final maturity, leading to a crash in the asset price. This theory also sheds light on the cause of many recent financial scandals and their link to the different accounting regimes. In fact, such a link has already been suggested by a recent report of the Bank of England (Michael [2004], p.120). As an example, the author cites the crisis of U.S. Savings and Loans, which

> [...] stemmed in part from the fact that the (variable) interest rates on their deposit liabilities rose above the (fixed) rates earned on mortgage assets. The application of traditional accounting meant that this showed up initially only gradually through negative annual net interest income. While it eventually became clear that many S& Ls were insolvent, a fair value approach would have highlighted much earlier that, as a result of changes in interest rates, the true economic value of their fixed-rate mortgage assets was below that of their deposit obligations. Had fair value accounting been used, it is likely that the S&Ls' difficulties would have been recognised and addressed earlier, and perhaps at lower fiscal cost.

Second, our model will help clarify the debate about the effect of different accounting regimes on asset price volatility. Opponents of a marking-to-market regime often claim that this accounting regime would lead to greater asset price fluctuations than would be the case under historic cost accounting. At first glance, this statement might seem consistent with intuition. But is this statement necessarily true? To the best of our knowledge, no theoretical model or empirical evidence has so far been presented that shows the impact of accounting regimes on asset price volatility. As our model shows, the claim that a historic cost accounting regime makes financial markets less volatile is not strictly true. Historic cost accounting indeed stabilizes asset prices in the short term. Under the veil of this apparent stability, volatility actually accumulates only to hit the market at a later date. Put differently, historic cost accounting not only transfers volatility across time but also increases asset price volatility overall. This result sits in stark contrast with the common opinion about historic cost accounting's effect on volatility.

Moreover, the model can, to some extent, provide a new explanation for the "Black" effect (Black [1976]). Under the historic-cost-accounting regime, we show that a low book value is followed by high uncertainty and hence high volatility of the next-period return.

Despite the current hot debate and the practical importance of the issue of accounting reform, there is surprisingly little theoretical and empirical work done on the economic consequences of different accounting regimes for the financial market. The leading article on this topic is the PSS paper. The authors study the basic trade-off between historic cost accounting and marking to market. In their model, the main problem of marking to market comes from the illiquidity of the secondary market. In such a market, the asset price is endogenous and the true and fair value of the asset is hence unavailable. The paper mainly concentrates on the position of a financial institution. It sheds light on why the opposition of marking to market is led by the banking and insurance industries. While we agree with PSS on the main problem of marking to market being its infeasibility, our paper mainly concentrates on the modeling of the economic consequences of the historic-cost-accounting regime, particularly its effect on asset prices, its link to market crashes, and its interplay with market transparency. Other papers that study the effects of marking to market on financial institutions include Strausz [2004] and Freixas and Tsomocos [2004].

Myers and Jin [2004] is one of the few papers to model the relationship between market transparency and asset price crashes as well as stock price co-movement while providing evidence in support of their theory. In their paper, using different proxies for transparency, the authors find that countries where firms are more opaque to outside investors exhibit a higher frequency of crashes. In comparison with their model, our paper builds on quite different premises and provides a new theory that explains the existing empirical evidence. Moreover, besides making explicit the effect of market transparency on crashes, our paper models the relationship between the accounting regime and asset price crashes.

Bushman, Piotroski, and Smith [2004] examine the factors that determine corporate transparency at the country level. They find that financial transparency is lower in countries with a high share of state-owned enterprises. In addition, their findings show that corporate governance is more transparent in countries with higher levels of judicial efficiency and a common-law background as well as in countries where stock markets are more active and well developed.

Morck, Yeung, and Yu [2000] and Campbell et al. [2001] study the relationship between the characteristics of financial markets and stock price variation. They show that R^2 and other measures of stock market synchronicity are higher in countries with relatively low per-capita gross domestic product (GDP) and less-developed financial markets. Bushee and Noe [2000] analyze the link between corporate disclosure and stock price volatility. Compared with this literature, our paper analyzes the effect of the accounting regime on asset price volatility.

2. *The Model*

2.1 THE FIRM

Consider a firm that is owned by one representative shareholder. The shareholder employs the manager to run the firm. The firm has only one exogenously given project (or asset). The project lasts two periods from T_0 until T_2 when it will be liquidated by the shareholder. The whole life of the project spans across the dates T_0, T_1, T_{2-} to T_2. T_{2-} slightly precedes T_2. We use T_{2-} to model our assumption that the manager is shorter lived than the firm.[3] The initial acquisition cost (or the market value at T_0) of the project is normalized to unity. The project yields no intermediate cash flows over its life. However, the manager can choose to sell any proportion of the project at T_1 and T_{2-}.[4] The selling price is the market value of the project at those dates. The market value at T_1 for the whole project is equal to $1 \cdot (1 + \tilde{g}_1)$, where $\tilde{g}_1$ denotes the project's growth rate over the first period. Similarly, the market value at T_2 (or T_{2-}) is given by $1 \cdot (1 + \tilde{g}_1) \cdot (1 + \tilde{g}_2)$, where $\tilde{g}_2$ is the growth rate in the second period. Moreover, we assume that the growth rates $\tilde{g}_1$ and $\tilde{g}_2$ are positively autocorrelated. Specifically, the setup for $\tilde{g}_1$ and $\tilde{g}_2$ is $\tilde{g}_1 = \tilde{\varepsilon}_1$ and $\tilde{g}_2 = \rho \tilde{g}_1 + \tilde{\varepsilon}_2$, where $\tilde{\varepsilon}_1$ and $\tilde{\varepsilon}_2$ are independent and both follow uniform distributions: $\tilde{\varepsilon}_1 \sim Unif[-a, a]$ and $\tilde{\varepsilon}_2 \sim Unif[-b, b]$ with $a > 0$, $b > 0$, $\rho > 0$.

Two remarks about the growth rates $\tilde{g}_1$ and $\tilde{g}_2$ deserve mention. First, they are private information. The project is firm specific. Its intrinsic worth, and hence its market value, is only known to the manager; it is hidden from the outsider or only available to him at a prohibitive cost. Secondly, we use the assumption of positive autocorrelation mainly to illustrate the feature that the firm's performance in the first period is a signal of its performance in the following period.[5]

2.2 THE AGENTS

There are two types of agents in our model: the shareholder and the manager. The first assumption about the manager is that he is shorter lived

[3] At the same time, this timing setup highlights the fact that a longer-dated model is unsuitable for our purposes (we explain the last two points later on). This timing setup is thus the most tractable one.

[4] We assume this project is divisible. Take the example of a supermarket chain that operates outlets in different locations. Should the company decide to part with some or all of its branches, the latter could be sold off as a whole, in groups, or individually. An outsider would only be able to see the total transaction value but be unable to put a price on the individual branches. He would simply lack the expertise (firm-specific project) or find it uneconomical to do so (high cost).

[5] The assumption of positive autocorrelation can also be justified by empirical evidence (e.g., GDP growth, as an aggregate performance measure of numerous small projects, over the business cycle) and on theoretical grounds (e.g., stage financing in the venture capital industry as an optimal contract due to sequential information revelation).

than the project. Upon receiving his compensation at T_{2-}, he resigns and leaves the firm while the project remains alive until T_2. We believe the manager's shorter life relative to that of the project is a fundamental reason for the inefficiency caused by historic cost accounting. Since the project is liquidated at the later date T_2, its market value is unobservable to the outsider (including the shareholder) when the manager leaves the firm at T_{2-}. Hence market-value-based compensation is not available to incentivize the manager to maximize firm value (the shareholder's objective). Conversely, suppose the manager was longer lived than the project. Then the shareholder would be able to offer a compensation scheme linking the project's liquidation value to the manager's pay. In this case, first-best efficiency can be achieved.[6] Second, we assume that the manager is risk averse with utility displaying constant absolute risk aversion defined over wealth at time T_2 given by $U(\tilde{W}) = 1 - e^{-k \cdot \tilde{W}}$, where k denotes the coefficient of risk aversion. The shareholder is assumed to be risk neutral for simplicity.

2.2.1. The Information Structure. The agency problem in this model arises from the information asymmetry between the shareholder and the manager. The manager as the insider knows the intrinsic value[7] of the project at any point in time even if the project is not brought to the market to be sold. However, the shareholder as the outsider knows the intrinsic value of the project only when it is liquidated in the market at T_2. Prior to liquidation, the shareholder must rely on the firm's book value from the manager's accounting report, which depends on the particular accounting regime used, to infer the firm's market value. Under historic cost accounting, the firm's book value contains two parts. The portion of the project the manager chooses to sell is transferred to cash and therefore shown at its market price. The remaining part of the project that the manager chooses to hold is recorded at its initial cost. However, under marking to market, the book value of the firm is the market price of the whole project. If there exists a deep and liquid secondary market for the project, as we assume, its market price is exogenous (i.e., the firm is a price-taker unlike in the setup of the PSS model). In this case, first-best efficiency can be achieved under the marking-to-market regime since the book value is just equal to the market value of the firm. There is no information asymmetry between the manager and the shareholder.

2.2.2. The Compensation Structure. The objective function of the shareholder is to maximize the final liquidation value of the project at T_2. As for the manager's compensation structure, we consider different schemes. At this stage, we assume that the manager's objective is to maximize the book

---

[6] The shorter lifetime of the manager is also one of the reasons for the inefficiency of historic cost accounting in Plantin, Sapra, and Shin [2004].

[7] The intrinsic value is the value realized if the project is liquidated in the market.

value at T_{2-}. We show later on that this objective is equivalent to the manager being given accounting-number-based compensation—a base salary plus a profit bonus (the profit at T_{2-} is the book value at T_{2-} less the book value at T_0 (the initial cost of the asset)).[8] We believe the assumption of accounting-number-based compensation, particularly profit-based compensation, to be quite reasonable.[9] In fact, such compensation structures are widely used in practice, particularly in firms outside the United States. This is partly due to market inefficiency and illiquidity of some stock markets. Equity-based compensation may therefore cause even greater inefficiency not only in these countries. Even in the United States, where equity-based compensation is common, we still have good reason to believe that the stock price is significantly affected by accounting information. The assumption that the manager tries to maximize the accounting value does therefore not appear extreme.[10] Besides the monetary compensation, we assume that the manager derives some private benefit from running the project. Hence he prefers to continue operating over liquidating the project, all else equal. This assumption is the same in spirit as in Jensen [1986]. The manager prefers to have more and bigger projects despite their being value destroying (negative net present value).

2.2.3. The Agents' Actions. In this model, the manager's action is to choose α ($\in [0, 1]$), the proportion of the project he decides to sell at T_1 and T_{2-}. At T_1, conditional on the specific α the manager chooses, the book value of the project is equal to $BV_1 = \alpha \cdot (1 + g_1) + (1 - \alpha) \cdot 1 = 1 + \alpha \cdot g_1$, where g_1 is the realized growth rate of the project in the first period. The first term $\alpha\ (1 + g_1)$ is the book value of the part of the project that the manager chooses to sell, which equals its market price. The second term $(1 - \alpha)$ is the book value of the remaining part of the project the manager chooses to hold, which is recorded at its initial cost. Based on the book value BV_1, the shareholder makes the decision to either continue with or liquidate the *whole* project by trying to infer the fundamentals g_1. That is, the shareholder's action is $action^S$, where $action^S \in \{liquidate, continue\}$. Suppose the shareholder decides to continue with the project at T_1. Then the manager has another round of trading at T_{2-} just before leaving. Again, he can choose to sell any proportion of the remaining project at that date. The reason that we limit the shareholder's action to liquidating or continuing is because the manager's action is unverifiable and hence noncontractable. That is, the shareholder cannot force the manager to hold or sell a certain amount of the project. He can only passively choose to continue or liquidate the whole project.

---

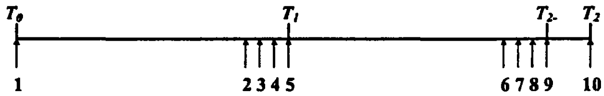
[8] In the extension part of this paper, we consider share-price-based compensation.

[9] However, if the shareholder decides to liquidate the whole project at T_1, we assume that the manager is paid based on the profit at T_1, which equals the liquidation value less the initial cost.

[10] The PSS paper also assumes that the agent's aim is to maximize the accounting value.

It is important to emphasize that the outsider can only observe the *total* book value $1 + \alpha \cdot g_1$. He cannot observe its two components separately: the sold part $\alpha \cdot (1 + g_1)$ and the unsold part $\alpha \cdot g_1$. In fact, no outsider, including the shareholder, can discern the project's growth rate g_1 by telling apart the cash $\alpha(1 + g_1)$ from the noncash item $(1 - \alpha)$. We use this setup to capture the fundamental difference between historic cost accounting and marking to market, namely that the shareholder cannot perfectly infer the market value from the book value.[11] Otherwise, there would be no difference between historic cost accounting and marking to market and the choice of which accounting regime is employed becomes irrelevant. If this is the case, there is no need to debate the accounting regime reform.[12]

2.3 THE TIMELINE OF EVENTS



Event	*Description*
1	The exogenous project is given.
2, 6	The manager observes the project's market value.
3, 7	The manager decides how much to sell or hold.
4, 8	The book value is disclosed.
5	The shareholder decides whether to continue or liquidate the whole project.
9	The manager receives compensation and then leaves the firm.
10	The whole project is liquidated.

FIG. 1.—Timeline.

2.4 THE DECISION RULES

Our analysis mainly concentrates on the agents' decisions at time T_1. Figure 2 describes the agents' decision rules at date T_1. Figure 2 also summarizes all the key information of the setup outlined so far.

[11] It is worth noting that even if these two items could be disentangled on the balance sheet, this can only occur when $\alpha \neq 0$. Therefore, if the manager's strategy in the equilibrium is to choose $a = 0$ for a very low g_1, then shareholders cannot infer g_1 even under the assumption that the balance sheet reports cash separately.

[12] In our context, the unobservability of the project's market value for the shareholder is due to its firm-specific nature and the heterogeneity of its parts. Take the example of the supermarket chain. In the case of a sale of a number of outlets that are regionally dispersed, for instance, the unit sale values are not known to the outsider, only the total sale value is. Although the outlets are likely to be identically equipped, the location factor is likely to drive a wedge between their individual sale values. Knowing or determining these values is not realistically possible for the outsider or only at a prohibitive cost. The inseparability of the proportion of the project sold and its growth rate, and thus the unobservability of the project's market value, is the crucial difference between historic cost accounting and marking to market. If the outsider could observe the growth rate and the proportion of the project sold individually, historic cost accounting would be just as informative as marking to market, making them identical.

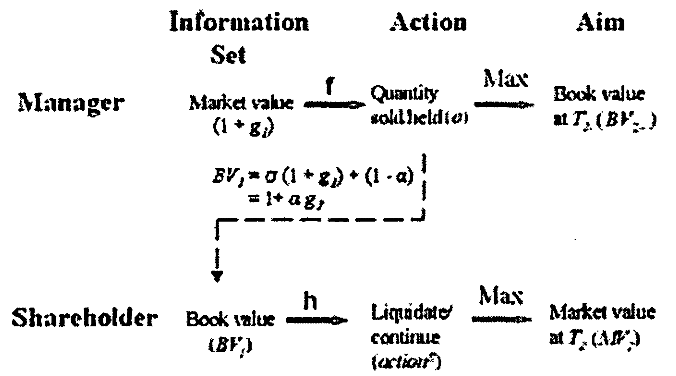


FIG. 2.—The agents' decision rules at time T_1. The manager observes the market value of the project. Based on this information, he decides how much to sell/hold to maximize his payoff linked to the book value at time T_2. However, when making his decision, the manager also needs to take the shareholder's possible response to his action into account. If the manager's action (forming a book value) results in the shareholder's decision to liquidate the whole project, the manager is no longer able to go ahead with the project and hence cannot maximize his payoff based on the book value at time T_2. He is then remunerated based on the liquidation value at time T_1. The shareholder uses the book value, which is a function of the fundamentals r_1 as well as the manager's action, as an (imperfect) signal to infer the firm's true performance r_1. Hence he makes the decision whether to continue or liquidate the whole project. His aim is to maximize the market value of the project at time T_2.

2.5 THE FINANCIAL MARKET

In our model, different financial markets are characterized by different degrees of transparency. To each financial market corresponds an "uninformed window" as shown in figure 3. The more transparent the financial market is, the smaller the "uninformed window." In our setup, where the project's return is uniformly distributed over the interval $[-a, a]$, we define the uninformed window as the subset $[-a', a']$ $(0 < a' < a)$. We assume that the outsider can perfectly observe the true value of states in the case of extreme return realizations (very high or very low) that fall outside the uninformed window. However, the shareholder cannot distinguish any given ex post return sampled inside the uninformed window from other returns in the uninformed window. The shareholder thus has to rely on the manager's accounting report for more information. The idea of defining an uninformed window can be described as follows. In every financial market, we can classify two kinds of communication channels between shareholders and management: accounting and nonaccounting reports. The nonaccounting channel is more powerful in transparent markets than in opaque ones. In fact, in more transparent financial markets like the United States, there is a greater analyst and media coverage through such institutions as investment banks and rating agencies for instance. All these nonaccounting channels make the shareholder less dependent on the manager's accounting report. Hence, the uninformed window, within which the shareholder has to rely

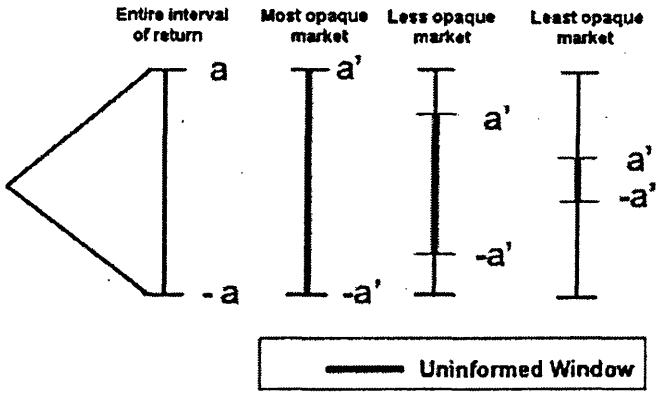


FIG. 3.—The financial market with different degrees of transparency. For the same project whose return is uniformly distributed in the interval $[-a, a]$, the less opaque finanical market has a shorter uniformed window $[-a', a']$, within which the shareholder has to rely on the accounting statement (the book value). Outside the uninformed window, the shareholder knows the true state.

on the manager's accounting report, is shorter.[13] We also use figure 3 to illustrate the setup of the financial market. Without loss of generality, we normalize the risk-free interest rate in the economy to zero.

3. The Equilibrium

As figure 2 shows, the agents' actions are not independent but there indeed exists a strategic dimension to their decision-making process. In fact, the interplay of their actions constitutes a sequential game between the shareholder and the manager. Solving for the equilibrium of the game is equivalent to finding the equilibrium strategy profile of the agents (f, h). We formalize the agents' strategies in definition 1.

DEFINITION 1 (*Strategies*). *The manager's strategy at time T_1 is the function f, which is a map from the first period's return g_1 to the proportion of the asset he chooses to sell α, that is, $\alpha = f(g_1)$. The shareholder's strategy is given by the function h, which maps the book value at time T_1 to the set {liquidate, continue}. That is, $action^S = h(BV_1)$, where $action^S \in$ {liquidate, continue}.*

It is important to note that the equilibrium does not only depend on the accounting scheme but also on the degree of transparency of the financial market. The degree of transparency determines the length of the

[13] Further, as the referee pointed out, we can also interpret the opaqueness measure a' as an LCM hurdle under the historic cost accounting regime in reality.

uninformed window, which in turn determines the manager's capability to mask the firm's true performance. Recall that the shareholder is perfectly informed, that is, his action does not depend on the disclosure of accounting information, when the economic fundamentals are recorded outside the uninformed window. Theorem 2 states the first type of equilibrium—a pooling equilibrium, which occurs in sufficiently opaque financial markets where the uninformed window is large. The proof of the theorem is provided later on.

THEOREM 2 *(Pooling Equilibrium). When $a' > a^*(b, \rho, k)$, the strategy profile $s = (f, h)$ at time T_1 constitutes a Nash equilibrium, where f and h satisfy*

$$f(g_1) = \begin{cases} \underset{\alpha \in [0,1]}{\arg\mathrm{Max}}\, E(U(\max(1 + \alpha g_1, \alpha(1 + g_1) & \textit{when } g_1 \geq 0 \\ \quad + (1 - \alpha)(1 + g_1)(1 + \tilde{g}_2)))) & \\ 0 & \textit{when } g_1 < 0 \end{cases}$$

and

$$h(BV_1) = \begin{cases} \textit{continue when} & BV_1 \geq 1 \\ \textit{liquidate when} & BV_1 < 1 \end{cases}.$$

In this equilibrium, the manager sells nothing (i.e., $f(g_1) = 0$) if and only if g_1 falls in two extreme intervals, this is $g_1 \in [-a', \underline{a}] \cup [\bar{a}, a']$. In the middle interval $[\underline{a}, \bar{a}]$, the manager partially liquidates the project, where $a^* = [\frac{3}{4}(\bar{a}^2 - \underline{a}^2) + \frac{1}{2}(\bar{a}^3 - \underline{a}^3)]^{\frac{1}{3}}$, $\bar{a}$ solves $\{e^{-k(1+\bar{a})(1+\rho\bar{a}+b)} \cdot [1 + k(1 + \bar{a})(\bar{a}\rho + b)] - e^{-k(1+\bar{a})(1+\rho\bar{a}-b)} \cdot [1 + k(1 + \bar{a})(\bar{a}\rho - b)]\} \times \frac{1}{2bk(1+\bar{a})} = 0$ and $\underline{a}$ satisfies $-k\underline{a}e^{-k\frac{\rho\underline{a}^2 + (1+\rho)\underline{a} - b(1+\underline{a})}{2b(1+\underline{a})}} + \frac{1}{2bk(1+\underline{a})}[e^{-k(1+\underline{a})(1+\rho\underline{a}+b)} - e^{-k} + k(1 + \underline{a})(\rho\underline{a} + b) \cdot e^{-k(1+\underline{a})(1+\rho\underline{a}+b)} + k\underline{a} \cdot e^{-k}] = 0$.

It is worth noting that the pooling equilibrium here is to be interpreted in the sense that the shareholder always continues the project, as opposed to the result in theorem 3 below where the firm is efficiently liquidated when $g_1 < 0$. The basic idea of the pooling equilibrium can be explained as follows. When the project's return in the first period g_1 is non-negative, the manager does not need to worry that the shareholder will liquidate the project. The manager can maximize his own expected utility without giving any consideration to the shareholder's interference. However, when the project's return g_1 is negative, the manager knows that the shareholder will definitely liquidate the whole project if the manager sells only a tiny fraction. It is thus optimal for the manager to set $\alpha = 0$. This is the manager's strategy. As for the shareholder, if he observes a book value strictly higher (lower) than unity, he can perfectly infer the project's return being positive (negative). Hence his dominant strategy is to continue (liquidate). Observing a book value of unity, he knows the project could be either very good or very bad. But if the uninformed window is sufficiently large (i.e., $a' > a^*(b, \rho, k)$), as we assume in theorem 2, the gain of continuing potentially good projects dominates the loss of not liquidating bad projects. The shareholder's optimal strategy is then to continue resulting in bad and good projects being pooled. In summary, the shareholder continues the whole project if the book value is not less than unity. Otherwise he liquidates the project.

Before proceeding to the proof of theorem 2, we use some diagrams created via numerical simulations of the agents' optimal strategies to help us understand the intuition behind the equilibrium. First, consider the manager's strategy. In figure 4, the bottom diagram represents the manager's strategy, the optimal sale α as a function of the fundamentals g_1. This is a nonmonotonic function. The manager sets $\alpha = 0$ (i.e., holds everything) when g_1 is very low or very high, selling partially when g_1 is fairly high. It is worth noting that the optimal α is the result of two different considerations by the manager. When $g_1 \geq 0$, α is the solution to the manager's utility maximization problem. In this case, he needs not be concerned with the shareholder's liquidating the firm, as we show later. When $g_1 < 0$, the manager's decision to sell nothing is given by his strategic consideration. The reason for his action is that he must otherwise fear the firm's forced liquidation by the shareholder, which would thwart the manager's chance of upside compensation at time T_{2-}. Following the manager's action (i.e.,

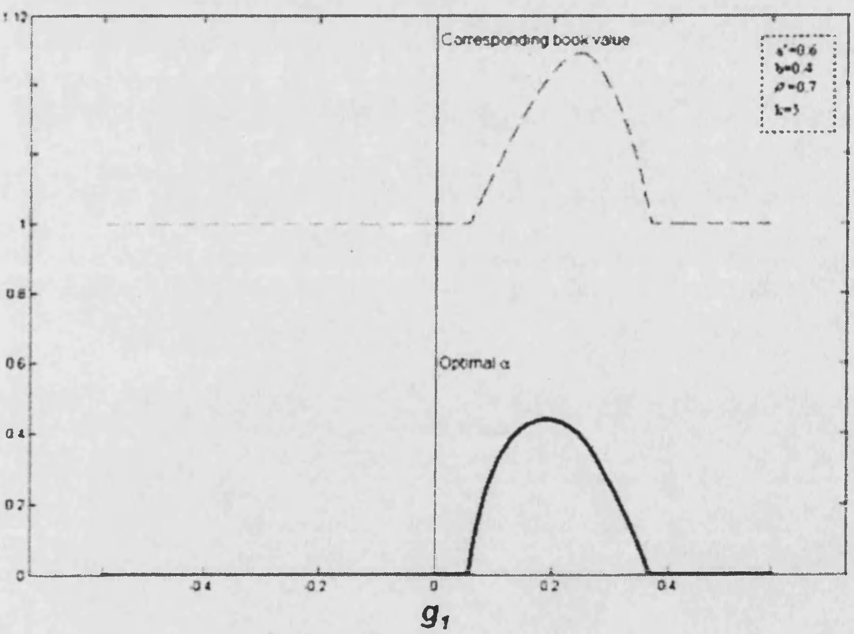


FIG. 4.— The manager's strategy in the pooling equilibrium.

choosing α), the shareholder can access the firm's accounting statements and observe its book value as shown in the top diagram of figure 4. Note that the book value is a bell-shaped function of the fundamentals. The book value is just a simple function of the manager's action (i.e., $BV_1 = \alpha(1 + g_1) + (1 - \alpha) = 1 + \alpha g_1$). In this diagram, we can see a pattern similar to the "Black" effect. That is, the lower the first-period expected return, the higher the volatility (uncertainty) of the next-period return. The shareholder uses the book value information to try to infer the fundamentals, that is, $g_1 = f^{-1}(BV_1)$. For a book value (y-axis) greater than unity, there are two corresponding values of g_1 (x-axis). As the book value decreases, the distance between the two g_1, which measures the uncertainty of the fundamentals, increases. Particularly, at a book value equal to unity, the corresponding g_1 falls into two intervals. At this point, the shareholder's uncertainty is at its highest.

Next, consider the shareholder's strategy. Conditional on the book value he observes, the shareholder is uncertain about the economic fundamentals. The top diagram in figure 5 plots his position. Particularly when he observes a book value of unity, the fundamental value may be any $g_1 \in [-a', \underline{a}] \cup [\bar{a}, a']$. This degree of uncertainty makes the shareholder's optimal strategy not obvious. The bottom diagram in figure 5 depicts the shareholder's payoffs of the two alternative choices (liquidate or continue) as functions of the fundamentals. Suppose the shareholder knows that the return falls inside $[0, \underline{a}] \cup [\bar{a}, a']$. In this case, his strategy to continue with

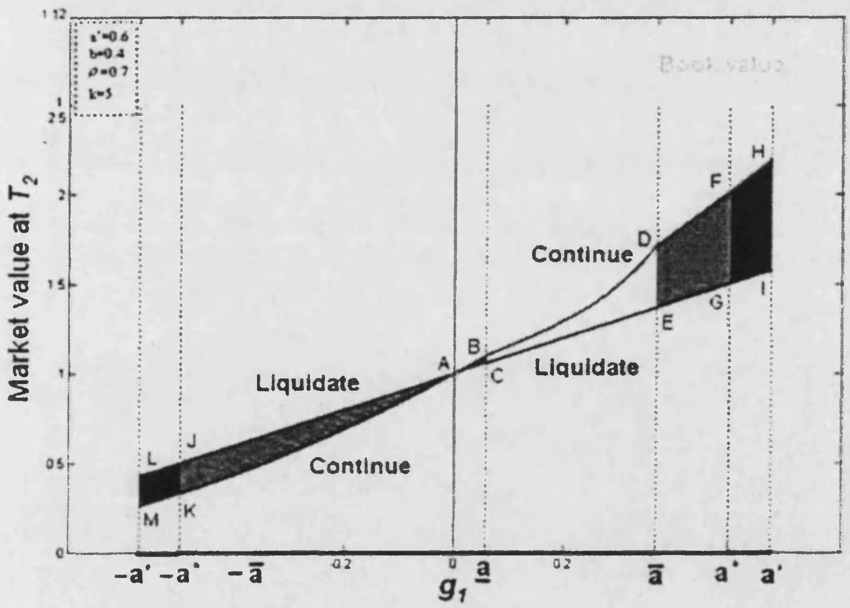


FIG. 5.— The shareholder's strategy in the pooling equilibrium.

the project dominates the decision to liquidate the firm early. However, if g_1 falls in the interval $[-a', 0]$, liquidation is the dominant strategy. Faced with uncertainty, the shareholder's strategy is to compare the potential gain (the area $\triangle$DHIE + $\triangle$ABC) with the potential loss (the area $\triangle$ALM) of a given strategy. The result of the comparison depends on the length of the uninformed window. The bigger the uninformed window (a') is, the higher the possibility that *continue* becomes the dominant strategy. a^* is the threshold. If $a' > a^*$, the shareholder lets the project continue, which corresponds to the pooling equilibrium in the sense that both bad and good projects are kept alive. If the shareholder observes a book value different from unity, continuation is the shareholder's dominant strategy as the diagram shows.

The above explanation forms the basic intuition for the pooling equilibrium in theorem 2. Now we can proceed with the formal proof.

Proof of Theorem 2. In essence, proving that the strategy profile (f, h) constitutes a Nash equilibrium is equivalent to proving that the strategy of each agent is the best response to that of the other agent (i.e., f and h are the best mutual responses). To aid comprehension, we organize the proof into a number of steps.

Step 1: If g_1 doesn't fall into the uninformed window (that is, $g_1 \in [-a, -a'] \cup [a', a]$), the shareholder knows g_1 perfectly. Hence, there is no inefficiency due to market opaqueness or the accounting regime. Hence, it suffices to focus the discussion only on $g_1 \in [-a', a']$.

Step 2: Consider the shareholder's strategy. Essentially the shareholder's decision to continue or liquidate is about the trade-off between liquidating the project at date T_1 and delaying liquidation until time T_2. Thus he needs to compare the time-T_1 market value of the project with its expected time-T_2 market value. The project's market value at T_1 is $MV_1 = 1 \cdot (1 + g_1) = 1 + g_1$. If the manager delays liquidation until time T_2, the project's T_2-market value includes two parts. The first part is the portion of the project the manager liquidated at T_1. This is in the form of cash, which was converted before T_{2-}. Its value is $\alpha\ (1 + g_1)$. The other part is the one the manager chooses to hold. Its value at T_2 is $(1 - \alpha)(1 + g_1)(1 + \tilde{g}_2)$. Hence, the total market value at T_2 is $MV_2 = \alpha(1 + g_1) + (1 - \alpha)(1 + g_1)(1 + \tilde{g}_2)$. Therefore, the expectation of the difference in payoff between the two alternative choices is

$$E[MV_2 - MV_1] = E[(1 - \alpha)(1 + g_1)\tilde{g}_2] = (1 - \alpha)(1 + g_1)\rho g_1. \quad (1)$$

From equation (1), we can see that the shareholder's decision exclusively depends on the fundamentals g_1. However, while the manager knows the fundamental value of the firm, the shareholder merely receives some information about it through the disclosure of accounts (i.e., the book value). The book value thus serves as a signal of the fundamentals. It reflects the decision of the manager, which in turn is a function of the fundamentals. Specifically, the book value is given by

$$BV_1 = \alpha(1+g_1) + (1-\alpha) = 1 + \alpha g_1. \tag{2}$$

Now we can discuss the shareholder's strategy, the function $action^S = h(BV_1)$. There are three cases for BV_1: (1) $BV_1 > 1$, (2) $BV_1 < 1$, and (3) $BV_1 = 1$. In cases (1) and (2), the shareholder can perfectly infer the sign of the economic fundamentals from the book value. Given that α is nonnegative, we have

$$BV_1 > 1 \Longrightarrow g_1 > 0, \tag{3}$$

$$BV_1 < 1 \Longrightarrow g_1 < 0. \tag{4}$$

Substituting equations (3) and (4) into equation (1) and considering the manager's equilibrium strategy $\alpha = f(g_1) \neq 1$, we obtain

$$BV_1 > 1 \Longrightarrow E[MV_2 - MV_1] > 0, \tag{5}$$

$$BV_1 < 1 \Longrightarrow E[MV_2 - MV_1] < 0. \tag{6}$$

From equations (5) and (6), we can get the shareholder's optimal strategy (i.e., his best response to the manager's strategy) in cases (1) and (2). That is, *continue* $= h(BV_1)$ when $BV_1 > 1$ and *liquidate* $= h(BV_1)$ when $BV_1 < 1$.

The more complicated part is case (3) when the book value equals unity. In this case, there are two things that can happen, either $g_1 = 0$ or $\alpha = 0$. In fact, whatever the fundamentals are, the book value will equal unity if the manager holds fully. The shareholder cannot perfectly infer the fundamentals. However, given the manager's strategy, the shareholder knows that the manager chooses $\alpha = 0$ if and only if $g_1 \in [-a', \underline{a}] \cup [\bar{a}, a']$. Hence, the expected net payoff from continuing the project conditional on a book value of unity is

$$\begin{aligned}
&E[MV_2 - MV_1 \mid BV_1 = 1] \\
&\quad = E[(1+g_1)\rho g_1 \mid BV_1 = 1] \\
&\quad = \frac{1}{2a' + \underline{a} - \bar{a}} \left(\int_{g_1=-a'}^{g_1=\underline{a}} (1+g_1)\rho g_1 \, dg_1 + \int_{g_1=\bar{a}}^{g_1=a'} (1+g_1)\rho g_1 \, dg_1 \right) \\
&\quad = \frac{1}{2a' + \underline{a} - \bar{a}} \left[\frac{2}{3} a'^3 - \frac{1}{3}(\bar{a}^3 - \underline{a}^3) - \frac{1}{2}(\bar{a}^2 - \underline{a}^2) \right].
\end{aligned} \tag{7}$$

From equation (7), we get the condition for the manager to continue the project conditional on the book value equal to unity. That is,

$$E[MV_2 - MV_1 \mid BV_1 = 1] > 0 \Longleftrightarrow a' > a^*$$

where

$$a^* = \left[\frac{3}{4}(\bar{a}^2 - \underline{a}^2) + \frac{1}{2}(\bar{a}^3 - \underline{a}^3) \right]^{\frac{1}{3}}. \tag{8}$$

In theorem 2, we assume $a' > a^*$, hence the shareholder continues with the project, which results in the pooling equilibrium. So far, we have shown that $action^S = h(BV_1)$ is indeed the shareholder's best response to the manager's strategy.

Step 3: Now consider the manager's strategy. The manager's information is the fundamental return g_1. Suppose the realized return is non-negative, $g_1 \geq 0$, then the book value $BV_1 = 1 + \alpha g_1$ is greater or equal to unity since α is non-negative. The analysis shows that the book value will be at least unity whatever the non-negative α the manager chooses when $g_1 \geq 0$. Considering that the shareholder's strategy is to continue the project if the book value is not less than unity, the manager needs not be concerned with the shareholder's liquidation of the project. The manager's objective is equivalent to maximizing expected utility, which is a function of his bonus at T_{2-}. The bonus is proportional to the firm's profit, which is the difference between the book value at T_{2-} and T_0 (i.e., the initial cost). We begin by analyzing the book value at T_{2-}, denoted BV_{2-}. As we have already shown in step 2, the market value of the project at T_2 is $MV_2 = \alpha(1 + g_1) + (1 - \alpha)(1 + g_1)(1 + \tilde{g}_2)$. Moreover, we know that the market value of the project at T_{2-} is $MV_{2-} = MV_2$. We must have

$$\begin{aligned} BV_{2-} &= \text{Max}(BV_1, MV_{2-}) \\ &= BV_1 + \text{Max}(0, MV_{2-} - BV_1). \end{aligned} \tag{9}$$

The intuition behind equation (9) is as follows. At T_{2-} when the manager leaves the firm, he has another opportunity to trade. He can choose to sell or hold the remainder of the project that is still "alive" (i.e., the portion of project that was not liquidated at T_1). At that date, if he chooses not to sell, the book value BV_{2-} is equal to the book value at the previous date (i.e., BV_1). This means the manager can report a book value at T_{2-} of at least BV_1. This is his "floor." The manager chooses not to sell at T_{2-} when the market value at that date, MV_{2-}, is lower than BV_1. It is then optimal for him to hold everything. Alternatively, if the market value MV_{2-} is higher than BV_1, he sells the remainder of the project to realize its market value. Hence, we can express the book value BV_{2-} as shown in equation (9). This equation also highlights the feature that the historic-cost-accounting regime gives the manager a free call option (i.e., a floor plus a call option). The idea behind the option feature of historic cost accounting is as in our analysis above: The manager can choose to sell (i.e., exercise the option) to make the book value reflect the market value when the market price is high. In addition, he can choose to hold (i.e., not exercise the option) to keep the book value unchanged when the market price is low.

Substituting MV_{2-} and BV_1 into (9), we obtain

$$\begin{aligned} BV_{2-} &= \text{Max}(BV_1, MV_{2-}) \\ &= \text{Max}(1 + \alpha g_1, \alpha(1 + g_1) + (1 - \alpha)(1 + g_1)(1 + \tilde{g}_2)). \end{aligned} \tag{10}$$

Therefore, the profit of the firm at T_{2-} is

$$\begin{aligned} PF_{2-} &= BV_{2-} - BV_0 \\ &= \mathrm{Max}(1+\alpha g_1, \alpha(1+g_1) + (1-\alpha)(1+g_1)(1+\tilde{g}_2)) - 1. \quad (11) \end{aligned}$$

Since we are concerned with the situation $g_1 \geq 0$, from equation (11) we have

$$PF_{2-} \geq 0. \quad (12)$$

It is worth noting that the compensation structure has the characteristic of "limited-liability," which means that the shareholder cannot pay a negative bonus in the case of a loss. Fortunately, however, we can see from equation (12) that the profit is always non-negative in our model. Hence, the limited-liability constraint is never binding.

Suppose the manager's bonus is a proportion $\beta > 0$ of the profit. The bonus is then equal to

$$\begin{aligned} BN = \beta \cdot PF_{2-} = \beta \cdot [&\mathrm{Max}(1+\alpha g_1, \alpha(1+g_1) \\ &+ (1-\alpha)(1+g_1)(1+\tilde{g}_2)) - 1]. \quad (13) \end{aligned}$$

Substituting equation (13) into the manager's utility function, we obtain his expected utility

$$\begin{aligned} EU &= E(U(BN)) \\ &= E(U(\beta \cdot PF_{2-})) \\ &= E(U(\beta \cdot [\mathrm{Max}(1+\alpha g_1, \alpha(1+g_1) \\ &\quad + (1-\alpha)(1+g_1)(1+\tilde{g}_2)) - 1])). \quad (14) \end{aligned}$$

Recall that the manager's utility function is $U(\tilde{W}) = 1 - e^{-k \cdot \tilde{W}}$. In order to save parameters, we can use an equivalent optimization scheme to replace the original one by replacing k with $k\beta$

$$\begin{aligned} \underset{\alpha \in [0,1]}{\mathrm{Max}}\, EU \Longleftrightarrow\ & \underset{\alpha \in [0,1]}{\mathrm{Max}}\, E(U(\beta \cdot [\mathrm{Max}(1+\alpha g_1, \alpha(1+g_1) \\ & + (1-\alpha)(1+g_1)(1+\tilde{g}_2)) - 1])) \\ \Longleftrightarrow\ & \underset{\alpha \in [0,1]}{\mathrm{Max}}\, E(U(\mathrm{Max}(1+\alpha g_1, \alpha(1+g_1) \\ & + (1-\alpha)(1+g_1)(1+\tilde{g}_2)))) \quad (15) \end{aligned}$$

where k is scaled up by β.

Basically, equation (15) shows that the manager's maximizing utility based on his bonus is equivalent to his maximizing utility based on book value.

Hence, we obtain the optimal strategy for the manager when $g_1 \geq 0$, that is,

$$f(g_1) = \arg\max_{\alpha\in[0,1]} E(U(\mathrm{Max}(1+\alpha g_1, \alpha(1+g_1) + (1-\alpha)(1+g_1)(1+\tilde{g}_2)))) \text{ when } g_1 < 0.$$

Finally, we need to show that the manager's optimal strategy is to sell nothing when $g_1 < 0$. By $BV_1 = 1 + \alpha g_1$, if the manager sets α to be positive, $BV_1 < 1$. Following the argument in step 2, the shareholder liquidates the firm immediately after observing $BV_1 < 1$. If this situation happens, the market value of the firm is realized and the manager's bonus is paid based on the firm's liquidation value. The liquidation value however is $MV_1 = 1 + g_1 < 1$, which means that the manager receives no bonus. This is not the manager's optimal strategy. In fact, he can do better by setting $\alpha = 0$, which makes the book value at T_1 equal unity. In this case, the shareholder lets the project continue according to his optimal strategy. The manager prefers this strategy of holding (i.e., $\alpha = 0$) for two reasons. First, if he can make the shareholder continue with the project, the manager receives a valuable "call option" and his bonus is non-negative. The option comes from the fact that there is a positive probability of the project's "recovery" at date T_{2-}. If recovery does occur, the manager can sell the project at that date, thus making a profit and earning a bonus. Even if "recovery" does not transpire and the firm's performance worsens, the shareholder can choose to hold the project at T_{2-}, setting the book value to at least unity. Therefore, the manager has an incentive to keep the project "alive." The second reason follows from the assumption that the manager derives some private benefit from continuing the project. This means that even though the manager knows perfectly that the project will not recover and may even worsen, he still prefers not to divest the project early since he can reap the private benefit in this case. He is also employed for another year and receives his guaranteed base salary. In sum, the manager's strategy is to set $\alpha = 0$ when $g_1 < 0$, that is,

$$f(g_1) = 0 \quad \text{when } g_1 < 0.$$

Step 4: In this step, we show $\underline{a}$ and $\bar{a}$ do exist so that the manager indeed holds fully when g_1 is high enough (i.e., $g_1 > \bar{a}$) and sells partially when g_1 is fairly high. That is, we need to show there do exist such optimal *a*s that make the book value a bell-shaped function of g_1. The mechanism can be explained as follows. As we showed in step 2, the manager holds fully when $g_1 < 0$ due to his strategic concern that the shareholder would liquidate the project if he were to sell. However, we would ideally like to know the intuition for his choice to hold fully even when the return is very high. There are two reasons. One is the growth opportunity. The high return in the first period means that the expected return in the second period will be high. Second, as we argue in step 3, the manager has an option at date T_{2-}. However, only if he holds the project can he keep this option alive. Hence, he has an incentive to hold the project. However, why does the manager prefer to sell partially rather than hold fully when the fundamentals are fairly good? This is due to another two factors that make the decision tend in the opposite direction (i.e., favor selling). One is that the manager is risk averse. His decision to hold or sell is equivalent to making a portfolio choice. Selling the asset increases his position in the risk-free asset (i.e., cash), while holding the project is analogous to investing in the risky asset. The standard trade-off induces the manager to sell partially (i.e., investing some amount in the risk-free asset) when g_1 (the expected return of the risky asset) is not very high. The second force, which makes the manager sell a bit more, is the "floor," which is analyzed in step 3. The more the manager sells, the higher the book value the manager has at T_1. This increases the floor in the book value at T_{2-}, which is valuable to the manager.

This concludes the proof of theorem 2. ■

Theorem 2 presents the pooling equilibrium that occurs in less transparent markets. However, the more transparent the financial market is, the more independent the shareholder is of the manager's accounting report. The manager has less opportunity to mask the firm's performance by pooling the bad with the good project. This change could lead to the second kind of equilibrium—a separating equilibrium. We state this result in theorem 3.

THEOREM 3 (*Separating Equilibrium*). *When* $\bar{a} < a' \leq a^*(b, \rho, k)$, *the strategy profile* $s = (f, h)$ *constitutes a Nash equilibrium, where* f *and* h *are given by*

$$f(g_1) = \left\{ \begin{array}{ll} \text{Max}(\arg\max\limits_{\alpha\in[0,1]}(E(U(\max(1+\alpha g_1, \alpha(1+g_1) & \textit{when } g_1 > 0 \\ \quad + (1-\alpha)(1+g_1)(1+\bar{g}_2)))), \varepsilon) & \\ \qquad\qquad 0 & \textit{when } g_1 \leq 0 \end{array} \right\}$$

and

$$h(BV_1) = \left\{ \begin{array}{ll} \textit{continue when} & BV_1 > 1 \\ \textit{liquidate when} & BV_1 \leq 1 \end{array} \right\}$$

where ε *is a small positive number infinitely close to zero (we can also define it by* $\frac{1}{\varepsilon} = +\infty$), $a^* = [\frac{3}{4}(\bar{a}^2 - \underline{a}^2) + \frac{1}{2}(\bar{a}^3 - \underline{a}^3)]^{\frac{1}{3}}$, $\bar{a}$ *solves*

$$\left\{ \begin{array}{l} e^{-k(1+\bar{a})(1+\rho\bar{a}+b)} \cdot [1 + k(1+\bar{a})(\bar{a}\rho + b)] - \\ \quad e^{-k(1+\bar{a})(1+\rho\bar{a}-b)} \cdot [1 + k(1+\bar{a})(\bar{a}\rho - b)] \end{array} \right\} \times \frac{1}{2bk(1+\bar{a})} = 0$$

and $\underline{a}$ *satisfies* $-k\underline{a}e^{-k\frac{\rho\underline{a}^2 + (1+\rho)\underline{a} - b(1+\underline{a})}{2b(1+\underline{a})}} + \frac{1}{2bk(1+\underline{a})}[e^{-k(1+\underline{a})(1+\rho\underline{a}+b)} - e^{-k} + k(1+\underline{a})(\rho\underline{a} + b)e^{-k(1+\underline{a})(1+\rho\underline{a}+b)} + k\underline{a}e^{-k}] = 0.$

The emergence of the separating equilibrium is due to the uninformed window being shorter now. The manager can no longer pool the bad with the good project. It is worth noting that both the shareholder's strategy and the manager's strategy change in the separating equilibrium compared with their actions in the pooling equilibrium. As for the shareholder, he now

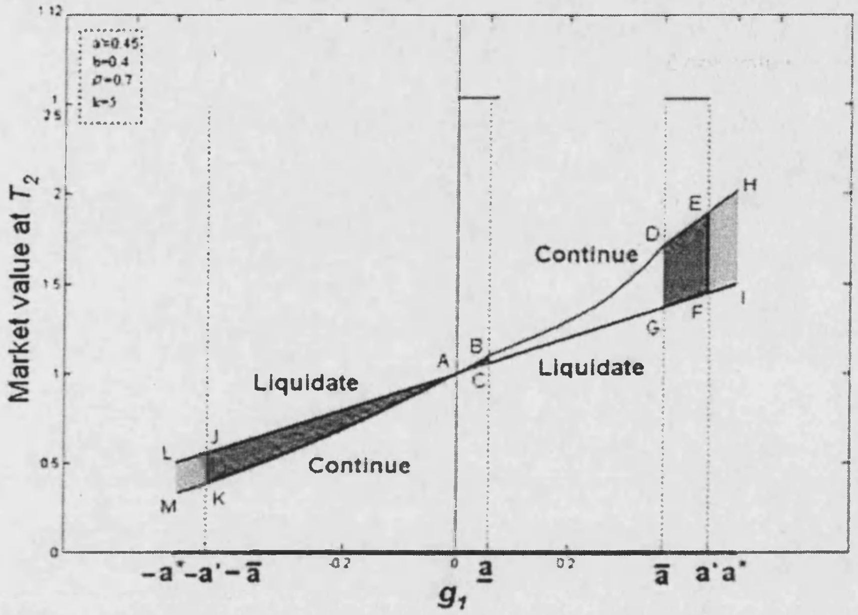


FIG. 6.— The shareholder's strategy in the separating equilibrium.

liquidates rather than continues the project after observing a book value of unity. The manager changes his strategy to selling a tiny proportion of the project to signal to the shareholder that the project is good when it is indeed good.

Figure 6 describes the result of the separating equilibrium. The top diagram is the shareholder's book value information. Suppose the manager still adopts his optimal strategy from the pooling equilibrium (i.e., sending no signal to the shareholder). The book value then corresponds to the dashed line in the diagram. If this is the case, conditional on the book value of unity, the shareholder's potential gain from continuation (the area of △ABC plus △DEFG) is dominated by the potential loss from early liquidation (the area △AJK). This is due to the uninformed window being shorter now ($a' \leq a^*$). Note that a^* is the threshold (i.e., △ABC + △DHIG = △ALM). Therefore, the shareholder's optimal strategy is to liquidate the project conditional on a book value of unity. The manager's strategy changes as well. He signals to the shareholder by showing a book value infinitesimally higher than unity when the economic fundamentals are positive. The solid line in the top diagram represents the manager's signal in terms of the book value. Now the shareholder can perfectly distinguish the bad from the good project and first-best efficiency can be achieved.

Proof of Theorem 3. The proof of theorem 3 is rather easy as we only need to compare the agents' strategies in the separating equilibrium with those in the pooling equilibrium. The change of the shareholder's strategy in the separating equilibrium is his action deviation when he observes a book value of unity. Since the uninformed window is shorter now (i.e., $a' \leq a^*$ (b, ρ, k)), condition (8) is no longer satisfied. The shareholder liquidates the project. The idea behind this argument is as follows. Although the shareholder knows the project may be very good conditional on a book value of unity, the loss from a poor project dominates the gain from a promising project. Hence, it is optimal for the shareholder to liquidate the project. It is very important to note that the manager's strategy also changes when the shareholder's strategy does. Conditional on the manager's selling nothing giving rise to a book value of unity, the manager knows that the shareholder will liquidate the project even if there is a chance of it being good. Hence the manager has to adapt his strategy in order to maximize his payoff: He sends an inimitable signal to the shareholder that the project is good when indeed the economic fundamentals are good by selling a tiny fraction ε of the project to push the book value slightly above unity. Hence, $f(g_1)$ is the best response of the manager to the shareholder's strategy. Now we can go back and check that the shareholder's strategy is still the best response to the manager's updated strategy. This is in fact obvious. Given the manager's strategy, the shareholder knows the book value equals unity if and only if $g_1 < 0$. Now it is even more certain that the shareholder liquidates the project in this case. ■

4. *The Implications*

In this section, we analyze the model implications by a series of propositions. From theorems 2 and 3, we know that in more opaque financial markets the manager is better able to use historic cost accounting to pool bad with good projects. This hinders the shareholder from discerning the bad project at an early stage. The bad project can then potentially worsen in quality over time. The poor performance can accumulate and only eventually surface, leading to a big crash in the asset price. This is the relationship between market transparency and the asset price crash.

PROPOSITION 4. *Under the historic-cost-accounting regime, a higher degree of opaqueness leads to more frequent and more severe asset price crashes.*

The result of Proposition 4 is consistent with the findings in Myers and Jin [2004]. Our contribution is that we provide a new mechanism that explains the cause of the empirical evidence. In other words, the historic-cost-accounting regime can provide a tool for the manager to hide the firm's true performance, a scenario that can potentially lead to a crash.

Figure 7 gives a numerical example. On the horizontal axis we plot a' (i.e., the width of the uninformed window) and on the vertical axis Δs (i.e., the degree of the crash in the book value). The graph shows that more opaque financial markets exhibit a higher intensity of book value crashes, both in frequency and magnitude.

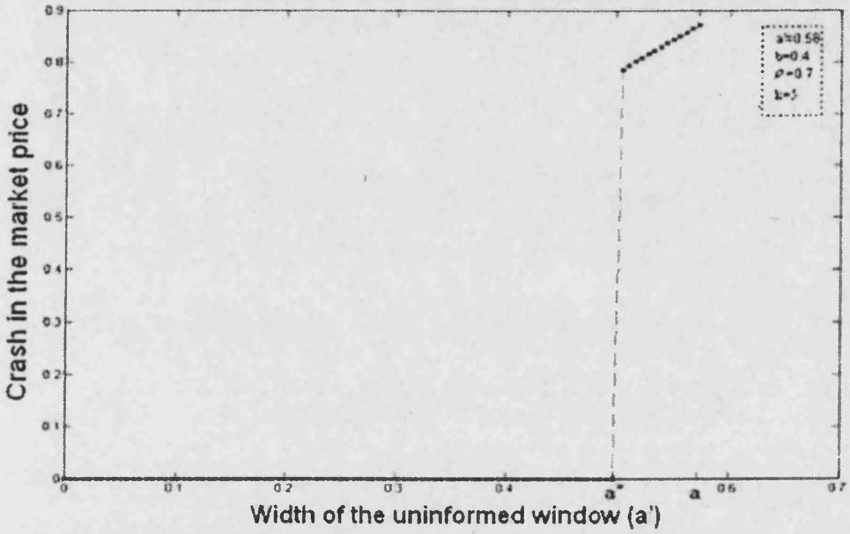


FIG. 7.— The crash in the asset price.

Proof of Proposition 4. See appendix.

Now consider what happens if the marking-to-market regime can be implemented (in the sense that the fair value is observable). In this case, the shareholder can see through the firm's performance. He liquidates the firm if $\varepsilon_1 = -a'$ and no crash can happen. Yet there is a crash under historic cost accounting if the financial market is sufficiently opaque. This is Proposition 5: the relationship between the accounting regime and the asset price crash.

PROPOSITION 5. *In an opaque financial market (i.e., $a' > a^*$), more severe and more frequent asset price crashes result under historic cost accounting than under marking to market.*

Proposition 5 is in the same spirit as Proposition 4. We therefore omit its proof.

In fact, some practitioner reports have provided evidence in support of the implication of Proposition 5. As a Bank of England survey states, under historic cost accounting the shareholder cannot distinguish the bad from the good project at an early stage and hence is unable to prevent a bad project from being kept alive and potentially worsening in quality. This is the reason for the crash under the historic-cost-accounting regime, while no such crash can happen under marking to market. The above argument underlines the intuition of Proposition 5.

As marking to market can lead to more efficient liquidation, the bad project will have a lower probability of survival over time. The asset price at T_2 is less volatile under marking to market than under historic cost accounting.

PROPOSITION 6. *The unconditional volatility of the asset price at T_2 is higher under historic cost accounting than under marking to market.*

Moreover, the historic-cost-accounting regime not only increases the asset price volatility overall but it also transfers it across time in a pattern similar to the "Black" effect. As figure 4 shows, under historic cost accounting, the lower (higher) the book value at T_1, the higher (lower) the uncertainty (volatility) about the liqudiation value at T_2.

PROPOSITION 7. *Under historic cost accounting, the asset price exhibits a pattern similar to the "Black" effect in the book value.*

5. Conclusion and Discussion

This paper analyzes the economic consequences of historic cost accounting for the financial market. Using a theoretical model we can (partially) answer the following two questions: What kind of inefficiency can a historic-cost-accounting regime cause and what is the mechanism that produces these inefficiencies? Our model shows that under historic cost accounting the opaqueness of the financial market can lead to the inefficient continuation of the project by the shareholder, which in turn leads to more pronounced asset price crashes, both in frequency and magnitude. However, under the marking-to-market regime, if the fair value is indeed available, these crashes do not happen. Our model also shows that historic cost accounting can change the asset price volatility. In fact, it transfers asset price volatility across time while increasing volatility overall. The mechanism of historic cost accounting to produce the above effects lies in the book value's convexity in the economic fundamentals. However low the market price is, the manager can make the book value equal to the initial cost (the floor) by holding the asset. At the same time, he can participate in the upside of the market valuation by selling. The convexity in the book value is equivalent to granting the manager a free-call option. When accounting-value-based compensation is used (which is quite common in reality), the manager has both the capability and the incentive to use this option. This leads to inefficiencies.

Finally, we admit that our results should be interpreted with caution since our results are based on a specific setup. It is impossible for us to explore all aspects of the features of historic cost accounting and all aspects of the effects of historic cost accounting. Notably, in the analysis of the equilibria and their implications, we assume that the manager's compensation structure is composed of a base salary plus a profit-based bonus. We use this assumption because such a compensation structure is widely used in practice, particularly in some industries like financial services. One of the most important reasons why many firms do not use market-value-based compensation under historic-cost-accounting in reality is that the market may be not very liquid, which makes the fair value unavailable. In this case, market-price-based compensation may cause more inefficiency. Also, the market price is likely to be very volatile and the market not efficient. Nevertheless, if the shareholder implements a very complicated compensation structure, this may reduce some inefficiency of the historic-cost-accounting regime.[14]

However, our argument is that many theoretical compensation structures are hardly feasible in reality, particularly given the illiquidity and inefficiency of many financial markets. In order to highlight and model the effects of historic cost accounting on a market with such features, we have abstracted away from the complicated optimal compensation design by using the compensation structure that is most common in reality. We believe our main findings are robust.

APPENDIX

Proof of Proposition 4. Consider the change in the share price between T_1 and T_2 in different financial markets. Here we suppose that the ex post returns in period 1 and 2 are $\varepsilon_1 = -a'$ and $\varepsilon_2 = -b$, respectively, that is, the lowest returns are realized. We consider this situation for the purpose of exploring the asset price change in extreme cases (i.e., the worst outcome). Note that when ε_1 falls outside the uninformed window (e.g., $-a < \varepsilon < -a'$), the shareholder can observe the return. Hence, the lowest ex post return that the shareholder cannot observe is $\varepsilon_1 = -a'$.

A transparent financial market: $a' \leq a^*$. In such a market, the whole project is liquidated at T_1. Hence, there is no change in the share price between T_1 and T_2.

$$\Delta s = s_1 - s_2 = 0. \tag{16}$$

[14] Our basic argument is that under historic cost accounting, share-price-based compensation is more efficient than accounting-value-based compensation if the stock market is sufficiently efficient. However, under marking to market, accounting-value-based compensation is an improvement over share-price-based compensation if the stock market is not liquid enough. Basically, given two accounting schemes and two compensation schemes, there are four pairwise combinations between the accounting regime and the compensation scheme: (1) historic-cost-accounting regime and accounting-value-based compensation, (2) historic-cost-accounting regime and share-price-based compensation, (3) marking to market and accounting-value-based compensation, (4) marking to market and share-price-based compensation. We argue that combinations (2) and (3) are more efficient than (1) and (4). Intuitively, (1) and (4) make the performance measure endogenous. Since the manager can influence the performance measure, which determines his pay, higher inefficiency ensues. Combination (1) is the focus of our paper. As we show, historic cost accounting provides the manager with a free option to increase the book value without requiring any effort from the manager. If the manager is remunerated based on book value, he has an incentive to use this free option. This leads to inefficiency. A similar story holds for combination (4). If marking to market and a share-price-based measure are used to determine compensation, the share price is no longer exogenous. This is so because the manager can influence the share pice to some degree himself. If his remuneration is simultaneously based on the share price, the manager has an incentive to inflate the share price to increase his compensation, which also leads to inefficiency.

Here we assume that if the project is liquidated early at T_1, the firm value at T_2 equals its liquidation value (e.g., all the cash generated from liquidation is retained within the firm until date T_2). Therefore, the firm value does not change in the second period.

An opaque financial market: $a' > a^*$. In such a market, the manager is able to pool bad with good projects by exploiting the shareholder's ignorance of the project's true quality leading the shareholder to potentially continue both types of projects. The book value is unity. Hence, the share price is the discounted expected market value of the firm at T_2 conditional on the book value at T_1 being unity, that is,

$$
\begin{aligned}
s_1 &= E(MV_2 \mid BV_1 = 1) \\
&= E[(1+g_1)(1+\rho g_1 + \tilde{\varepsilon}_2) \mid BV_1 = 1] \\
&= \frac{1}{2a' + \underline{a} - \bar{a}} \cdot \left[\int_{-a'}^{\underline{a}} (1+g_1)(1+\rho g_1) dg_1 + \int_{\bar{a}}^{a'} (1+g_1)(1+\rho g_1)\, dg_1 \right] \\
&= \frac{1}{2a' + \underline{a} - \bar{a}} \\
&\quad \cdot \left\{ \begin{aligned} &\left[\frac{1}{3}\rho \underline{a}^3 + \frac{1}{2}(\rho+1)\underline{a}^2 + \underline{a}\right] - \left[-\frac{1}{3}\rho a'^3 + \frac{1}{2}(\rho+1)a'^2 - a'\right] \\ &+ \left[\frac{1}{3}\rho a'^3 + \frac{1}{2}(\rho+1)a'^2 + a'\right] - \left[-\frac{1}{3}\rho \bar{a}^3 + \frac{1}{2}(\rho+1)\bar{a}^2 - \bar{a}\right] \end{aligned} \right\}.
\end{aligned}
$$

The share price at T_2 is the firm's liquidation value at that date given by $s_2 = (1-a')(1-\rho a' - b)$.

Therefore, the price change is equal to

$$
\begin{aligned}
\Delta s &= s_1 - s_2 \\
&= \frac{1}{2a' + \underline{a} - \bar{a}} \\
&\quad \cdot \left\{ \begin{aligned} &\left[\frac{1}{3}\rho \underline{a}^3 + \frac{1}{2}(\rho+1)\underline{a}^2 + \underline{a}\right] - \left[-\frac{1}{3}\rho a'^3 + \frac{1}{2}(\rho+1)a'^2 - a'\right] \\ &+ \left[\frac{1}{3}\rho a'^3 + \frac{1}{2}(\rho+1)a'^2 + a'\right] - \left[-\frac{1}{3}\rho \bar{a}^3 + \frac{1}{2}(\rho+1)\bar{a}^2 - \bar{a}\right] \end{aligned} \right\} \\
&\quad - (1-a')(1-\rho a' - b). \qquad (17)
\end{aligned}
$$

Putting equation (16) and (17) together, we obtain Δs, which measures the extent of the asset price crash, as a function of a', which measures the degree of market opaqueness:

$$\Delta s = l(a')$$

$$= \left\{ \begin{array}{ll} 0 & a' \in [0, a^*] \\ \dfrac{1}{2a' + \underline{a} - \bar{a}} \cdot \left\{ \begin{array}{l} \left[\dfrac{1}{3}\rho \underline{a}^3 + \dfrac{1}{2}(\rho+1)\underline{a}^2 + \underline{a}\right] \\ -\left[-\dfrac{1}{3}\rho a'^3 + \dfrac{1}{2}(\rho+1)a'^2 - a'\right] \\ +\left[\dfrac{1}{3}\rho a'^3 + \dfrac{1}{2}(\rho+1)a'^2 + a'\right] \\ -\left[-\dfrac{1}{3}\rho \bar{a}^3 + \dfrac{1}{2}(\rho+1)\bar{a}^2 - \bar{a}\right] \end{array} \right\} & a' \in (a^*, a] \\ -(1-a')(1-\rho a' - b) & \end{array} \right\}.$$

With the setup of the parameters in our model, Δs is an increasing function of a' when the crash occurs (i.e., $a' \in (a^*, a]$), which means that the more opaque financial market displays more severe crashes. Moreover, Δs is a discontinuous function of a' in the whole interval $[0, a]$. When $a' < a^*$, there is no crash at all. This discontinuity means that opaqueness not only leads to more severe but also more frequent asset price crashes. This idea becomes clearer if we consider the case of multiple projects. Suppose there are many projects in each financial market, the length of the uninformed window of these projects in the same financial market is different but centered around a' of their own financial market. Hence, we can expect that the financial market with a higher a' will have more projects falling within the interval $(a^*, a]$, resulting in a higher frequency of crashes.

REFERENCES

ANONYMOUS. "A Question of Measurement." *The Economist* (October 23, 2004): 83.

BALL, R.; A. ROBIN; AND G. SADKA ."Is Accounting Conservatism Due to Debt or Equity Markets? An International Test of 'Contracting' and 'Value Relevance' Theories of Accounting." Working paper, University of Chicago, 2005.

BLACK, F. "Studies of Stock Price Volatility Changes." *Proceedings of the 1976 Meetings of the American Statistical Association*, Washington, DC, 1976.

BUSHEE, B., AND C. NOE. "Corporate Disclosure Practices, Institutional Investors, and Stock Return Volatility." *Journal of Accounting Research* 58(2000): 171–202.

BUSHMAN, R.; R. PIOTROSKI; AND A. SMITH. "What Determines Corporate Transparency?" Working paper, University of Chicago, 2004.

CAMPBELL, J., AND L. HENTSCHEL. "No News Is Bad News: An Asymmetric Model of Changing Volatility in Stock Returns." *Journal of Financial Economics* 31 (1992): 281–318.

CAMPBELL, J.; M. LETTAU; B. MALKIEL; AND Y. XU. "Have Individual Stocks Become More Volatile? An Empirical Exploration of Idiosyncratic Risk." *Journal of Finance* 56 (2001): 1–43.

CHRISTIE, A. "The Stochastic Behavior of Common Stock Variances: Value, Leverage and Interest Rate Effects." *Journal of Financial Economics* 3 (1982): 407–32.

DENS, D. "Discussion of Accounting Discretion in Fair Value Estimates: An Examination of SFAS 142 Goodwill Impairments." *Journal of Accounting Research* (2006): 289–96.

FIGLEWSKI, S., AND X. WANG. "Is the 'Leverage Effect' a Leverage Effect?" Working paper, NYU Stern School of Business, 2002.

FREIXAS, X., AND D. TSOMOCOS. "Book vs. Fair Value Accounting in Banking and Intertemporal Smoothing." Working paper, Pompeu Fabra University and Oxford University, 2004.

HART, O., AND J. H. MOORE. "A Theory of Debt Based on the Inalienability of Human Capital." *Quarterly Journal of Economics* 109 (1994): 841–79.

JENSEN, M. C. "The Agency Costs of Free Cash Flow: Corporate Finance and Takeovers." *American Economic Review* 76 (1986): 323–29.

MICHAEL, I. "Accounting and Financial Stability," in *Financial Stability Review*. Bank of England, London, 2004: 118–28.

MORCK, R.; B. YEUNG; AND W. YU. "The Information Content of Stock Markets: Why Do Emerging Markets Have Synchronous Stock Price Movements?" *Journal of Financial Economics* 58 (2000): 215–60.

MYERS, S. C., AND L. JIN. "R^2 Around the World: New Theory and New Tests." *Journal of Financial Economics* 79 (2006): 257–92.

PLANTIN, G.; H. SAPRA; AND H. S. SHIN. "Marking-to-Market: Panacea or Pandora's Box?" Working paper, Carnegie Mellon University, University of Chicago, and London School of Economics, 2004.

SCHWERT, W. "Why Does Stock Market Volatility Change over Time?" *Journal of Finance* 44 (1989): 1115–1153.

STRAUSZ, R. "The Effect of Fair vs. Book Value Accounting on the Liquidity and Investment Behavior of Banks." Working paper, Free University of Berlin, 2004.