Illiquid Assets and Short Term Debt: Banks*

Paul Schure

University of Victoria, Canada

May 2002

Abstract

This paper studies the financing of firms that engage in activities of which the quality is difficult to observe and verify by outside investors. I present a model that shows that the managerial performance of such firms is enhanced by investments in illiquid assets combined with short-term debt finance. Thus, there are synergies between the firm's unobservable activities and illiquid assets, provided that the firm's financial structure hinges on short-term debt. I apply the theory to banking firms. The theory may explain why commercial banks have traditionally combined the activities of screening and monitoring projects with an illiquid loan portfolio and a short-term debt structure. JEL: G20, G32, L22.

*This is a revised version of the second essay of my dissertation written at the European University Institute. I would like to thank Pierpaolo Battigalli, David Cass and James Dow for their supervision. I also thank Merwan Engineer, Eugene Kandel, Rainer Kiefer, Yehuda Kotowitz, Colin Mayer, David Weil, participants at the 1999 Meeting of the Association of Southern European Economic Theorists (ASSET); participants of 'Financial Systems and Institutions in the Third Millennium', May 2000, Jerusalem; and seminar participants at Tel Aviv University, Hebrew University, the Norway School of Management, BI, the Bank of International Settlements (BIS), and the University of Victoria. Special thanks go to Franklin Allen, Pierpaolo Battigalli and Joseph Zeira for their very detailed comments and encouragement. Any remaining errors are mine. Most of the work of this paper was done while I was on a TMR fellowship at Hebrew University. I thank Hebrew for its kind hospitality and the Pinhas Sapir Economic Policy Forum and TMR network FMRX-CT96-0028 of the EU for financial support. Correspondence: Department of Economics, University of Victoria, PO Box 1700, Victoria (BC), Canada V8W 2Y2. Tel: +1 250 721 8535. Fax: +1 250 721 6214. Email: schure@uvic.ca.

Illiquid Assets and Short Term Debt: Banks

Abstract

This paper studies the financing of firms that engage in activities of which the quality is difficult to observe and verify by outside investors. I present a model that shows that the managerial performance of such firms is enhanced by investments in illiquid assets combined with short-term debt finance. Thus, there are synergies between the firm's unobservable activities and illiquid assets, provided that the firm's financial structure hinges on short-term debt. I show that the theory applies to banks. The theory may explain why commercial banks have traditionally combined the activities of screening and monitoring projects with an illiquid loan portfolio and a short-term debt structure. JEL: G20, G32, L22.

1 Introduction

The focus of this paper is on the financing of firms that engage in activities of which the quality is difficult to observe or verify. Examples of such firms include start-up firms in the hightech industry, start-up internet firms, and also many "monitoring firms" such as banks and finance companies, management consultants, auditing companies, rating agencies, and venture capital funds.

The model presented in the paper shows that the performance of such firms is enhanced by investments in illiquid assets combined with a financial structure that hinges on short-term debt. More precisely, the model assumes that managerial effort is unobservable. It shows that managerial effort is boosted by the presence of illiquid assets, provided that the firm is financed with short-term debt. Thus, with a short-term debt structure, there are synergies between the firm's 'opaque' activities and illiquid assets.

The leading example of the theory shall be a (commercial) bank. Banks exert costly effort in screening and monitoring projects and firms. Leland and Pyle (1977) and Campbell and Kracaw (1980) have advanced that the quality of these screening and monitoring activities are difficult to observe and verify ('opaque') by nature. Morgan (2000) shows that banks are opaque by presenting evidence in the form of difference of opinion of bond raters. A notable example where bad monitoring was not detected for a long time was the 1997 Asian financial crisis. Many have claimed the crisis was the result of a misallocation of capital by local banks that went unnoticed for several years. Banks also satisfy the empirical prediction of the theory. First, banks invest in illiquid assets in the form of an illiquid loan portfolio (e.g. Bhattacharya and Thakor, 1993) and reputational capital (Boot, Greenbaum and Thakor, 1993). Second, banks run a serious liquidation risk by financing these illiquid assets by taking a considerable amount of short term debt (deposit) finance.

The model focuses around the financing problem of a *risky project*. The expected surplus of the risky project depends on the amount of effort exerted by the agent that undertakes the risky project. Effort is costly and is exerted after the contract is signed. Effort is also assumed to be unobservable (and nonverifiable) so that outside investors in the risky project *free-ride* on the effort exerted by the agent who undertakes the risky project. It is a standard result that a serious enough free-rider problem leads to a suboptimal level of effort production (e.g. Jensen and Meckling (1976) or Diamond (1984)).

The agent who can best mitigate the free-rider problem should undertake the risky project. In the risk-neutral setting of the model the wealthiest investor is an obvious candidate because she seems to stand to lose the most when not exerting effort. However, the model shows that in some circumstances an agent called the *illiquid project holder* who has the idea for an *illiquid project* can be a better monitor. Two necessary conditions are (1) that the illiquid project holder also undertakes in the illiquid project and (2) that she attracts short-term debt finance to finance both projects. Thus, in order to be better than the wealthy investor, the illiquid project holder must found a firm that has two assets and a fragile financial structure, and that engages in effort to screen and monitor the risky project: a *bank*.

Although the model distinguishes two distinct projects, notice that the model does not exclude that these projects are attached to a single bank asset in reality. Indeed, the only relevant feature of the risky project in the model is that it requires effort production. Banks engage in costly effort production when screening and monitoring investment projects. From this viewpoint, the risky project represents the bank's screening and monitoring activities, while the illiquid project the bank's investments in some of these investment projects.

A crucial model assumption is that the illiquid project holder cannot credibly commit to surrender all the future rents the illiquid project generates.[1] As a result the illiquid project has a low liquidation value and a low capacity to attract external finance (a low 'debt capacity'). The intuition to the result of the paper is now easily understood. When the illiquid project holder chooses short-term debt finance to undertake both projects she stands to lose the future rents accruing from the illiquid project. In particular, in case investors observe a bad signal regarding the risky project, they liquidate the assets of the illiquid project holder, and thus bar access to the future rents of the illiquid project. In order to make the risky project work and keep the future rents of the illiquid project, the illiquid project holder exerts a high level of effort. Summarizing, the illiquid project holder has an incentive to stay in control of the illiquid project, and this incentive is used to precommit to exert a high amount of effort to make the risky project a success. Long-term finance does not work because in this case the illiquid project holder retains the rents of the illiquid projects independently of the outcome of the risky project.

There is scope for the theory of this paper in case that the quality of managerial effort is difficult to assess (the firm is opaque) and other incentive mechanisms fail to bring managerial effort to an acceptable level. In many industries the quality of managerial effort is relatively easily to assess; often simply by comparing the firm's financial statements with those of its competitors. In this case, outside investors can monitor management effectively. By contrast, for the firms that are relevant to this study the amount and the quality of the effort that is exerted is not observable. It is assumed in addition that at the future moment when the efficacy of the effort exerted today becomes apparent, management cannot appropriately be punished.[2] Even if managerial effort is unobservable, some common incentive mechanisms may bring managerial effort to an acceptable level. For example, it could well be that for most start-up internet firms the prospect of a huge possible surplus leaves enough scope to subject management to high-powered incentive schemes (while still leaving outside investors with enough surplus). However, for firms such as commercial banks such incentive schemes may not be feasible, in which case the theory applies.

The theory advanced in this paper has roots that can be traced date back to two seminal papers in the area of banking, namely Diamond and Dybvig (1983) and Diamond (1984). As in Diamond and Dybvig (1983) the theory stresses the importance of the bank's fragile financial structure. However, in Diamond and Dybvig the bank's fragile financial structure is a natural consequence of the assumptions that high-yield investment technologies are long-term, and that the preferences of savers are unverifiable, but possibly short-term. In this paper, the fragile financial structure follows endogeneously from the need to incentivize the banker. Diamond (1984) inspires this paper in that the bank is opaque, i.e. the monitoring activities of the banker are unobservable. However, project diversification in Diamond is enough to incentivize the banker. In case perfect diversification is possible, Diamond shows, the bank's financial structure is irrelevant. In this paper perfect project diversification is not possible so that additional incentives are needed to motivate the banker. In the paper these additional incentives are provided by illiquid assets and a fragile financial structure.

The theory is closely related and complementary to the growing strand of the banking literature that stresses the positive incentive effects of short term debt, and in particular deposits, on bankers. In Calomiris and Kahn (1991), Qi (1997) and Diamond and Rajan (2001) deposit finance creates the right incentives for the bank manager. As soon as the bank manager shirks or cheats, depositors run and disintermediate the bank. Disintermediation strips the bank manager of (unmodeled) control rents, so that the bank manager is diligent and honest in equilibrium, and depositors never run the bank. Thus, in the papers above, as well as in this paper, a fragile financial structure is beneficial from an *ex ante* point of view.

The most important difference between this paper and Calomiris and Kahn (1991), Qi (1997) and Diamond and Rajan (2001) regards the informational assumptions of the depositor and the resulting new role of the illiquid asset as a punishment device.[3] Specifically, in Calomiris and Kahn (1991), Qi (1997) and Diamond and Rajan (2001) the threat to punish the bank manager by disintermediating the bank only works because the performance of the bank manager is *observable* (though unverifiable). By contrast, in this paper depositors cannot observe the managerial performance of the bank manager. Instead, there are two mild informational assumptions, namely that depositors observe (1) a signal of the return of the risky project after the investment date, but before the illiquid asset matures, and (2) whether the illiquid asset is still there (as in Myers and Rajan, 1998). Since in my model mismanagement remains undetected, depositors *cannot* promptly run the bank following mismanagement. In my model the bank is punished by (inefficient) liquidation of the illiquid asset. Punishment is possible as long as the illiquid asset is there; possibly long after mismanagement takes place.[4]

Flannery (1994) is more remotely related to my paper. He argues that banks risk a run because for banks short-term debt offers the only feasible resolution to the Myers' (1977) 'underinvestment' (i.e. risk-shifting) problem. With short-term debt banks no longer have an incentive to harm debt holders by taking on projects that are too risky because this would directly translate into more expensive short-term debt. In Flannery (1994) the risk of inefficient liquidation is a necessary negative by-product of short-term debt finance. This paper differs fundamentally because it stresses the beneficial (ex ante) effect of the risk of inefficient liquidation.

In the next section I present the model. I will first present the details of the risky project. After that I show under which conditions the open capital market finances and monitors the risky project. It turns out that the wealthiest investor is the best monitor. I next show under which circumstances the illiquid project holder outperforms the market in terms of effort production regarding the project. I conclude the next section by a simple example of the model. Section 3 shows that the loan portfolio of a bank, or its reputational capital satisfy the properties of the illiquid asset of the model. Section 3 also presents new European and North-American data to verify the accepted stilized fact that banks are liquidity mismatched. Section 4 concludes.

2 The Model

2.1 Overview and the Risky Project

Consider a competitive financial market with risk-neutral *investors* and let for simplicity the expected rate of return be zero. Time is divided into two periods with relevant dates date 0, date 1 and date 2. There are two investment opportunities, a *risky project* and an *illiquid project*. The *risky project* is big in that a group of investors is needed to bring together the investment amount that is needed. The expected return on the risky project depends on (monitoring) *effort*. Assume effort implies disutility and is unobservable for other agents. In addition, assume that in case more agents exert effort, they fully duplicate their efforts.[5] Full duplication of efforts implies that monitoring will be delegated to a single agent: the lead investor, or *monitor*. The monitor is the same agent as the delegated monitor of Diamond (1984) or Winton (1995) or the manager of Jensen and Meckling (1976). The idea to the *illiquid project* is owned by an agent called the *illiquid project holder* (IPH). The focus of the model is on the financing of the risky project and we defer the discussion of the illiquid project and IPH until later.

The particulars of the risky project are summarized in Figure 1. The risky project requires an investment amount of I_0 at date 0. At date 2 the risky project matures. The return is random: with probability $Q(e)$ the risky project becomes a *success* and yields a (verifiable) return of A_2; and with probability $1 - Q(e)$ the risky project is a *failure,* in which case nothing is produced. The probability of a success is a function of the effort level, $e \geq 0$, of the monitor. I assume throughout the paper that $Q(.)$ is a continuous function and that there is a threshold effort level $\underline{e} \geq 0$ below which the success probability of the risky project is zero. Possibly, also, there is an effort level $\overline{e} > \underline{e}$ above which the success probability stays constant. Finally, I assume that between $\underline{e}$ and $\overline{e}$ the success probability is strictly increasing in effort, but at a decreasing rate.

$$Q(e) = 0 \qquad 0 \leq e \leq \underline{e} \tag{1}$$

$$Q'(e) > 0 \text{ and } Q''(e) < 0 \qquad \underline{e} < e < \overline{e} \leq \infty \tag{2}$$

$$Q(e) = Q(\overline{e}) \leq 1 \qquad e \geq \overline{e} \tag{3}$$

At date 1, the investors observe a signal about the outcome of the risky project. In the simple setting that I adopt, the signal is perfect. In other words, investors costlessly observe at date 1 what the date-2 return of the risky project will be. The assumption that the signal is perfect is purely made for simplicity and can easily be generalized.

In the paper I maintain that the risky project should be undertaken in a first best world, i.e. there is a first-best effort level e^{FB} such that the surplus from the risky project is positive

$$S^{\text{Risky Project}}(e^{FB}) = Q(e^{FB})A_2 - e^{FB} - I_0 > 0 \tag{4}$$

Notice that in this case $e^{FB} = \min\{\overline{e}, \widetilde{e}\} > \underline{e}$, where $\widetilde{e}$ is implicitely defined by $Q'(\widetilde{e})A_2 - 1 = 0$.

2.2 The Benchmark: Open Market Finance

Call the case for which a generic investor (I^{M}) becomes the monitor of the risky project the case of *open market finance*. Let I^{M} have wealth endowment fI_0, where $f < 1$ is the fraction of the risky project that I^{M} alone can finance. I^{M} can only invest in the risky project if she attracts sufficient funds from some other (outside) investors. In the model the interests of these other investors are perfectly aligned, so that they can be treated as a single entity (I^{N}).

Figure 2 gives the extensive form representation of the game that represents the open market finance case. In the figure the first (top) entry of the payoff vector represents I^{M}'s payoff and the second (bottom) entry I^{N}'s payoff. The game assumes that I^{M} has all the bargaining power *vis a vis* I^{N}. The first three stages take place at date 0. In stage 1, I^{M} offers a contract $k = \langle L_0, D_1, D_2 \rangle$ to I^{N}, where L_0 is the amount I^{M} receives from I^{N} at date 0, D_1 is the stipulated repayment to I^{N} at date 1, and D_2 is the stipulated repayment to I^{N} at date 2. Notice that k cannot stipulate effort e, because effort is unverifiable. We have $L_0 \geq (1-f)I_0$ because enough needs to be borrowed for investment, and $D_2 \leq A_2$ because I^{M} gets at best A_2 out of the risky project. Assume without loss of generality that $D_1 = 0$.[6] At this level of abstraction, $k = \langle L_0, 0, D_2 \rangle$ can be viewed as a debt contract that stipulates a repayment amount of D_2, or as an equity contract that entitles I^{N} to a share of $\frac{D_2}{A_2}$ in the revenues of the risky project.

In stage 2, $\mathrm{I^N}$ either accepts or rejects k. If $\mathrm{I^N}$ rejects k, the game ends and both $\mathrm{I^M}$ and $\mathrm{I^N}$ receive a zero payoff (the investment opportunity is assumed to be foregone). If $\mathrm{I^N}$ accepts k, the game moves on to stage 3. In this stage, $\mathrm{I^M}$ chooses effort e. In stage 4 (date 1), nature picks the date-2 outcome of the risky project. The surplus is divided as follows at date 2. In case the risky project is a success, $\mathrm{I^M}$ receives $A_2 - D_2 + L_0 - I_0 - e$, while $\mathrm{I^N}$ gets $D_2 - L_0$. In case of a failure, $\mathrm{I^M}$ gets $L_0 - I_0 - e$, and $\mathrm{I^N}$ gets $-L_0$.

The equilibrium concept I adopt is subgame perfect Nash in pure strategies. We are interested in whether in equilibrium an investor is willing to undertake the risky project, and, if so, how much effort is put into monitoring.

Definition 1 *The open capital market is willing to undertake the risky project if there is at least one investor I^M with wealth endowment $\overline{f}I_0$, say, such that in equilibrium of the financing game above the risky project is undertaken.*

Using backward induction to solve the game delivers the result that the open market is willing to undertake the risky project if and only if there is an investor with a wealth endowment $\overline{f}I_0$ such that Program OMF below has a feasible solution

$$\max_{e,L_0,D_2} Q(e)(A_2 - D_2) - e + L_0 - I_0 \tag{Program OMF}$$

$$\text{s.t } L_0 \geq (1-\overline{f})I_0 \tag{5}$$

$$e \in \arg\max_{\widetilde{e}} \{Q(\widetilde{e})(A_2 - D_2) - \widetilde{e}\} \tag{6}$$

$$Q(e)D_2 - L_0 \geq 0 \tag{7}$$

$$Q(e)(A_2 - D_2) - e + L_0 - I_0 \geq 0 \tag{8}$$

The first restriction expresses that enough finance needs to be raised to make the investment possible. The second restriction is the incentive compatibility constraint. The third and last restrictions are I^{N}'s and I^{M}'s participation constraints, respectively.

If a solution to Program OMF exists, it is easily obtained. First, restriction 6 shows that for every repayment requirement D_2 there is a unique effort level e. Second, I^{N}'s participation constraint must bind in the optimum. Finally, restriction 5 also binds in the optimum: there is no 'over-borrowing'. To see whether a solution exits, verify whether equation 8 is satisfied. The next proposition shows that Program OMF has a unique solution (e^M, L_0^M, D_2^M) if and only if the endowment of the investor exceeds some lower threshold $\underline{f}$. Moreover, the proposition shows that if the solution satisfies $e^M < \overline{e}$ then we also have $e^M < e^{FB}$, i.e. the effort level is sub-efficient. Finally, the proposition shows that if $e^M < \overline{e}$ then effort is strictly increasing in I^{M}'s endowment.

Proposition 1 *(Solution to Program OMF)*

(i) If there is a solution to Program OMF, it is unique.

(ii) There is a $\underline{f} < 1$ *such that Program OMF has a solution if and only if* $\overline{f} \geq \underline{f}$*.*

Assume Program OMF has a solution (e^M, L_0^M, D_2^M) *for which* $e^M < \overline{e}$*.*

(iii) We have $L_0 = (1 - \overline{f})I_0$ *(there is no over-borrowing) and* $\underline{e} < e^M < e^{FB}$.

(iv) e^M, L_0^M, *and* D_2^M *can be viewed as functions of* f *in a small enough open interval* F *that contains* $\overline{f}$*. In particular, we have* $\frac{de^M}{df} > 0$, $\frac{dL_0^M}{df} < 0$ *and* $\frac{dD_2^M}{df} < 0$.

Proof. See Appendix.

A trivial consequence of Proposition 1 (iv) is that the wealthiest investor dominates the other investors in monitoring the risky project. Therefore, redefine $\overline{f}I_0$ to be the endowment of the *wealthiest* investor. In the remainder of this paper I focus on the situation in which the market is willing to undertake the risky project, but does not deliver the first-best effort level. A subefficient effort level arises because I^{N} *free-rides* on I^{M}'s effort provision.

Assumption 1

(a) $\overline{f} \geq \underline{f}$*, where* $\overline{f}$ *is the endowment of the wealthiest investor.*

(b) Let (e^M, L_0^M, D_2^M) *be the solution to Program OMF for* $f = \overline{f}$*. We have* $e^M < \overline{e}$*.*

Proposition 2 *If Assumption 1 holds then (a) the open market is willing to finance the risky project and (b) the open market exerts a subefficient amount of effort in monitoring the risky project:* $e^M < e^{FB}$*.*

Proof. Combine Assumption 1 and Proposition 1.

2.3 Intermediation by the Illiquid Project Holder

In the last subsection I showed that, under Assumption 1, the market does not reach the first-best effort level when financing the risky project. In this subsection I show that IPH can potentially be a better monitor provided she sets up a firm that undertakes *both projects* and is financed with *short-term debt*.

The illiquidity feature of the illiquid project is modeled by embedding it into an incomplete contracting framework.[7] Let the return be decomposed in a *cash* component and an *asset* component, and assume that cash returns cannot be specified in financial contracts because they are non-verifiable (by courts). Figure 3 presents the illiquid project. The illiquid project requires an investment amount i_0 at date 0, and it delivers c_2 units of cash and a_2 units of assets at maturity at date 2. At date 1 the assets can be *liquidated*, i.e. separated from IPH and sold for the amount of a_1. Assume for simplicity that liquidation is a zero-one decision. The surplus of the illiquid project is thus

$a_2 + c_2 - i_0$	if the illiquid project is not liquidated
$a_1 - i_0$	if the illiquid project is liquidated

I assume that the liquidation value is lower than the net present value of the cashflows of the illiquid project, i.e. liquidation at date 1 is inefficient. I also assume that the assets of the illiquid project depreciate over time, and that the size of the illiquid project is within bounds when compared to the risky project

$$a_1 < a_2 + c_2 \tag{9}$$

$$a_1 > a_2 \tag{10}$$

$$a_1 - i_0 < \overline{f} I_0 \tag{11}$$

Recall, from Proposition 2 that $\overline{f} I_0$ is the wealth endowment of the wealthiest investor. Equation 11 expresses that the wealthiest investor is richer than IPH in a sense that will be made precise later.

One option of IPH is to try to undertake only the illiquid project. IPH could also seek enough finance to undertake both the illiquid project and the risky project.[8] In this case IPH become the delegated monitor of Diamond (1984) for $\mathrm{I^N}$.

IPH only undertakes the illiquid project. Consider first the case in which IPH offers a contract to $\mathrm{I^N}$ to undertake only the illiquid project. The contract k can be short-term, i.e. of the form $k = \langle L_0, D_1, 0 \rangle$, or long-term, i.e. of the form $\langle L_0, 0, D_2 \rangle$. Mix-forms, i.e. contracts of the form $\langle L_0, D_1, D_2 \rangle$ with $D_1 \neq 0$ and $D_2 \neq 0$, do not add generality because liquidation is a zero-one decision. In this setting there is again no reason to borrow more than is invested, so assume $L_0 = i_0$. Notice also that k can be interpreted as a *debt contract* without loss of generality. A debt contract specifies that the borrower loses *control* of her assets to the lender in case of default. In this case 'control' just means the right to decide whether to continue or to liquidate the illiquid project.

Since cash revenues are non-verifiable there are limits to the amount that IPH can credibly commit to pay back at date 2. In particular, assume that IPH has all the ex post bargaining power so that the *renegotiation game* at date 2 is as in Figure 4. It is easy to see that in equilibrium IPH offers to repay $P_2 = \min\{a_2, D_2\}$ and $\mathrm{I^N}$ just accepts P_2.

Thus the maximum amount that IPH can commit to pay back at date 2 equals a_2 and we thus focus without loss of generality on contracts k with $D_2 \leq a_2$. Such contracts are *not* renegotiated in equilibrium.

The financing game between IPH and I^{N} in case IPH only undertakes the illiquid project looks as follows.

Stage 1 (date 0) IPH offers k to I^{N}.

Stage 2 (date 0) I^{N} accepts or rejects k.

- If k is rejected, both parties attain zero payoff.
- If k is accepted and is a long-term contract, IPH receives a payoff of $a_2 + c_2 - D_2$, while I^{N} gets $D_2 - i_0$.
- If k is accepted and is a short-term contract, the game continues at date 1.

Stage 3 (date 1) (IPH tries to 'roll over' k) IPH proposes to I^{N} to replace the old contract $k = \langle i_0, D_1, 0 \rangle$ by a new one, say, $k' = \langle i_0, 0, D_2' \rangle$, where $D_2' \leq a_2$.

Stage 4 (date 1) I^{N} either accepts or rejects k'.

- If I^{N} accepts k', IPH receives a payoff of $a_2 + c_2 - D_2'$, while I^{N} gets $D_2' - i_0$.
- If I^{N} rejects k', the illiquid project is liquidated. In this case IPH receives $a_1 - D_1$ and I^{N} $D_1 - i_0$.

The equilibrium of the game is simple. IPH has all the bargaining power at all dates and gets all the surplus. The project is undertaken when it is efficient to do so. Liquidation can be inefficient, however, since IPH can maximally commit to pay back a_2 at date 2.

Lemma 1 *If $i_0 > a_1$ the illiquid project is not undertaken. If $a_2 < i_0 \leq a_1$ the illiquid project is undertaken, but it is liquidated at date 1. If $i_0 \leq a_2$ the illiquid project is* *undertaken and continued at date 1. In equilibrium I^N gets* 0 *surplus. IPH's equilibrium surplus is given by*

$$S^{Illiquid\ Project} = \begin{cases} 0 & \text{if } i_0 > a_1 \\ a_1 - i_0 & \text{if } a_2 < i_0 \leq a_1 \\ a_2 + c_2 - i_0 & \text{if } i_0 \leq a_2 \end{cases}$$

IPH undertakes both projects. Now consider the case in which IPH wishes to invest in both the illiquid project and the risky project. Below I give the relevant financing game between IPH and $\mathrm{I^N}$. The solution is derived in the next subsection.

It is again useful to first solve the renegotiation game between IPH and $\mathrm{I^N}$ at date 2. Assume the required repayment of IPH to $\mathrm{I^N}$ is D_2. The renegotiation game is similar to the renegotiation game of Figure 4; only the payoffs of IPH and $\mathrm{I^N}$ differ because this time $\mathrm{I^N}$ has invested $i_0 + I_0$ and IPH now controls $a_2 + A_2$ assets at date 2 and has exerted effort e. IPH's equilibrium offer is

$$\begin{aligned} P_2^s &= \min\{D_2, a_2 + A_2\} \quad \text{in case the risky project is a success} \\ P_2^f &= \min\{D_2, a_2\} \qquad\quad \text{in case the risky project is a failure} \end{aligned} \tag{12}$$

In equilibrium liquidation does not take place so that equation 12 gives the equilibrium transfer from IPH to $\mathrm{I^N}$ at date 2.

Now turn to the financing game. Again, assume without loss of generality that there is no overborrowing: $L_0 = i_0 + I_0$. In the first stage IPH can offer a long-term debt contract $k = \langle i_0 + I_0, 0, D_2 \rangle$ or a short-term debt contract $k = \langle i_0 + I_0, D_1, 0 \rangle$.[9] From now on denote the former case the case of *long-term debt finance* and the latter the case of *bank finance.* Equation 12 shows that we can assume $D_2 \leq a_2 + A_2$ without loss of generality in the case of long-term debt finance.

Figure 5 depicts the subgames that correspond to the cases of long-term debt and bank finance. The first stages of both subgames are identical. IPH offers a contract k to $\mathrm{I^N}$ and

$\mathrm{I^N}$ either accepts or rejects k. If $\mathrm{I^N}$ accepts k, IPH invests in both projects and next decides how much effort to exert. If $\mathrm{I^N}$ rejects k, the game ends with both IPH and $\mathrm{I^N}$ having zero surplus. As from date 1 the subgames differ. In the case of long-term finance nature first selects the outcome of the risky project. From equation 12 we know that in equilibrium IPH repays $P_2 = \min\{D_2, a_2 + A_2\} = D_2$ in case of a success, and $P_2 = \min\{D_2, a_2\} = a_2$ in case of a failure.[10] In the case of debt finance IPH tries to roll over k at date 1 by offering a new contract. Call this new contract $k_1^s = \langle i_0 + I_0, 0, D_2^s \rangle$ in case of a success, and $k_1^f = \left\langle i_0 + I_0, 0, D_2^f \right\rangle$ in case of a failure. From equation 12 we know that $D_2^s \leq a_2 + A_2$ and $D_2^f \leq a_2$ without loss of generality. $\mathrm{I^N}$ either accepts the new contract, or she rejects it and then liquidates IPH's projects.

The solution concept is again subgame perfect Nash in pure strategies. We are interested in whether IPH *outperforms* the open capital market (in effort production for the risky project).

Definition 2 *(outperformance) IPH outperforms the open capital market if IPH undertakes the risky project in equilibrium and exerts higher effort than the wealthiest investor.*

The next lemma shows that with long-term debt IPH does *not* outperform the open capital market.

Lemma 2 *With long-term debt IPH cannot outperform the open capital market.*

Proof. See appendix. The intuition is the following. Suppose the illiquid project and the risky project were financed with long-term debt. Figure 5 (a) shows that, in equilibrium, IPH reaps the cash revenues of c_2 *independently of the outcome of the risky project.* IPH therefore only risks losing the remaining part of the surplus of the illiquid project, i.e. $a_2 - i_0$, by undertaking both projects. So, in a sense $a_2 - i_0$ is the wealth amount that IPH brings in. However, equations 10 and 11 show that $a_2 - i_0$ is smaller than $\overline{f} I_0$, i.e.

the endowment of the wealthiest investor. Proposition 1 (iv) thus shows that IPH cannot outperform the open capital market. □

Bank finance. Let us now consider the case of bank finance. The next lemma establishes from Figure 5 (b) that IPH would like to use bank finance to undertake both projects, if and only if Program BF below has a solution.

$$\max_{e,L_0,D_1} Q(e)(a_2 + c_2 + A_2 - D_1) - e \qquad \text{(Program BF)}$$

$$\text{s.t } L_0 = i_0 + I_0 \qquad (13)$$

$$D_1 \leq a_2 + A_2 \qquad (14)$$

$$e \in \arg\max_{\widetilde{e}} \{Q(\widetilde{e})(a_2 + c_2 + A_2 - D_1) - \widetilde{e}\} \qquad (15)$$

$$Q(e)D_1 + (1 - Q(e))a_1 \geq L_0 \qquad (16)$$

$$Q(e)(a_2 + c_2 + A_2 - D_1) - e \geq S^{\text{Illiquid Project}} \qquad (17)$$

Lemma 3 *IPH is willing to undertake both projects if and only if Program BF has a solution. IPH can potentially only outperform the open capital market with bank finance, i.e. using a short-term debt contract* $k = \langle i_0 + I_0, D_1, 0\rangle$*. In case the risky project fails,* I^N *liquidates IPH's assets at date 1. In case the risky project is a success, IPH successfully proposes to replace* k *by* $k_1^S = \langle i_0 + I_0, 0, D_1\rangle$ *at date 1.*

Proof. The proof follows from Figure 5 (b) and Lemma 2. See appendix.

Program BF and Lemma 3 show that IPH receives $a_2 + c_2 + A_2 - D_1 - e$, i.e. all project returns minus the repayment requirement and disutility from effort in case of a successful risky project, and only $-e$ in case of a failure. By contrast, I^{N} attains a payoff of $D_1 - L_0$ (success) or $a_1 - L_0$ (failure). Restriction 14 is necessary for IPH to successfully roll over

k at date 1 in case of a success (remember that $a_2 + A_2$ is the maximum amount that IPH can credibly promise to pay back at date 2 in case of a success). Restriction 15 is IPH's incentive compatibility constraint. Restriction 16 is $\mathrm{I^N}$'s participation constraint. The last restriction is IPH's individual rationality constraint: IPH is only willing to undertake both projects if it yields more than reaping the surplus of the illiquid project.

It is interesting to briefly translate Lemma 3 into the terminology of the banking literature. Use the term *bank* for the firm that IPH founds by issuing short-term debt to undertake both projects, and call the bank *fragile* if its creditors (here $\mathrm{I^N}$) inefficiently liquidate the bank in some states of the world (here: after $\mathrm{I^N}$ observes a bad signal with respect to the risky project at date 1). We have.

Corollary 1 *Only a fragile bank can potentially outperform the open capital market.*

The solution(s) to Program BF is obtained in exactly the same way as the solution to Program OMF. In particular, the participation constraint 16 binds in the optimum. Therefore, restrictions 13, 15 and 16 determine the candidate solution(s). It remains to be verified whether restrictions 14 and 17 are satisfied for these candidate solutions. In case more candidate solutions exist, pick the one that gives the highest objective.

Proposition 3 *(Solution to Program BF)*

(i) If there is a solution to Program BF, it is unique.

Assume Program BF has a solution (e^B, L_0^B, D_2^B). *Of course* $L_0^B = i_0 + I_0$

(ii) e^B *and* D_2^B *can be viewed as functions of the illiquid project returns in a small enough open interval that contains* $a_2 + c_2$. *In particular, if* $e^B < \overline{e}$ *we have* $\frac{de^B}{d(a_2+c_2)} > 0$ *and* $\frac{dD_2^B}{d(a_2+c_2)} < 0$

(iii) e^B *and* D_2^B *can be viewed as functions of the liquidation value of the illiquid project in a small enough open interval that contains* a_1. *In particular, if* $e^B < \overline{e}$ *we have* $\frac{de^B}{da_1} > 0$ *and* $\frac{dD_2^B}{da_1} < 0$. *However* $\frac{de^B}{da_1} < 0\Big|_{(a_1 - i_0 = constant)}$ *and* $\frac{dD_2^B}{da_1}\Big|_{(a_1 - i_0 = constant)} > 0$

Proof. See appendix.

Proposition 3 (ii) and (iii) show that an increase in the illiquid project returns or in its liquidation value has a positive effect on effort. However, interestingly, the proposition also shows that an increase in a_1 has a *negative* effect on effort if we keep IPH's 'wealth' $a_1 - i_0$ fixed. Notice that $\frac{a_1}{a_2+c_2}$ is a measure for the liquidity of the illiquid project. The comparative statics results can be summarized as follows. In principle, illiquidity of the illiquid project is a stimulus for IPH to exert effort. With less liquidity IPH loses more in case of liquidation.

Figure 6 plots possible solutions to Program OMF and Program BF respectively. In the graph the intersections of the solid lines sketch the solutions to Program OMF and Program BF. The curve called 'I^{M}: effort' represents equation 6 of Program OMF, and the curve 'I^{M}: PC' represents I^{N}'s binding participation constraint (i.e. restriction 7) where $L_0 = (1 - \overline{f})I_0$. The intersection of these two curves with the highest value of e is the solution of Program OMF, provided that the surplus of the risky project exceeds zero, i.e. provided that the dashed line SRP lies above the e-axis. Likewise, the intersection of the curves 'IPH effort' and 'IPH: PC' determines the solution for Program BF. The curve 'IPH effort' represents IPH's effort choice of equation 15, while 'IPH: PC' is I^{N}'s binding participation constraint 16 where $L_0 = i_0 + I_0$. Program BF specifies that possible solutions (e^B, L_0^B, D_2^B), with $L_0^B = i_0 + I_0$ should satisfy constraints 14 and 17. The dashed line DC represents the right-hand side of 14, and the dashed line IR is derived from 17 (i.e. it is the curve $D = a_2 + c_2 + A_2 - \frac{e + S^{\text{Illiquid Project}}}{Q(e)}$). Constraints 14 and 17 require that the solution must be under the curves DC and IR.

For the example in Figure 6 bank finance outperforms open market finance. However, this need not necessarily be the case. Indeed, the only thing that follows directly from Program OMF and Program BF is that the curve 'IPH effort' must lie above the curve

'I^{M}: effort', and that 'IPH: PC' must lie above 'I^{M}: PC'.

Figure 6 shows also what happens in case c_2 increases. In this case the curve 'I^{M}: effort' shifts outward, increasing IPH's effort. Thus, like Proposition 3 (ii), this suggests that for high enough c_2 we could well have that IPH outperforms the open capital market. The next proposition derives a stronger result, namely that under mild conditions and appropriately chosen c_2 IPH exerts the first-best level of effort. Needless to say, c_2 must be relatively large in order to let IPH achieve the first-best.

Proposition 4 *(Bank Finance versus Open Capital Market Finance)*
(i) In case $i_0 \leq a_2$ *we have: If* $i_0 + I_0 \leq Q(e^{FB})(a_2 + A_2) + (1 - Q(e^{FB}))a_1$ *and* $\frac{i_0+I_0-a_1}{Q(e^{FB})} - i_0 + I_0 - a_1 \leq S^{Risky\ Project}(e^{FB})$ *then for appropriate* c_2*, namely* $c_2 = \frac{i_0+I_0-a_1}{Q(e^{FB})} + a_1 - a_2$*, IPH outperforms the open capital market.*
(ii) In case $i_0 > a_2$ *we have: If* $i_0 + I_0 \leq Q(e^{FB})(a_2 + A_2) + (1 - Q(e^{FB}))a_1$ *then for appropriate* c_2*, namely* $c_2 = \frac{i_0+I_0-a_1}{Q(e^{FB})} + a_1 - a_2$*, IPH outperforms the open capital market.*

Proof. It can be verified straightforwardly that under the stated conditions $e^B = e^{FB}$, $L_0^B = i_0 + I_0$, and $D_2^B = \frac{i_0+I_0-a_1}{Q(e^{FB})} + a_1$ becomes the solution to Program BF if $c_2 = \frac{i_0+I_0-a_1}{Q(e^{FB})} + a_1 - a_2$.□

To conclude, notice that in case the risky project is riskfree for the first-best level of effort, i.e. $Q(e^{FB}) = 1$, then Proposition 4 simply states: If $i_0 + I_0 \leq a_2 + A_2$ then for appropriate c_2, namely $c_2 = i_0 + I_0 - a_2$, IPH outperforms the open capital market.

2.4 Example

Below I present a simple example of the model. In this example the open market is *not* willing to undertake the risky project, while IPH is willing to use bank finance to undertake both projects.

Let the risky project require an investment amount of $I_0 = 5/4$. If the risky project fails, no return is realized, and in case of a success it yields $A_2 = 5/2$. Assume that the wealthiest investor has a fund endowment of 1/4 so that $\overline{f} = 1/5$. With respect to monitoring, let

$$Q(e) = \begin{cases} 0 & \text{if} \;\; 0 \leq e < \frac{1}{3} \\ \frac{3e-1}{2e} & \text{if} \;\; \frac{1}{3} \leq e < 1 \\ 1 & \text{if} \;\; e \geq 1 \end{cases}$$

I first show that the open capital market is not willing to undertake the risky project. From restrictions 6 and 7 of Program OMF we find that $e = 1/2$ and $D_2 = 2$. However, for these values restriction 8 is not satisfied

$$Q(e)(A_2 - D_2) - e + L_0 - I_0 = \frac{1}{2}\left(\frac{5}{2} - 2\right) - \frac{1}{2} + 1 - \frac{5}{4} < 0$$

Now let us see whether IPH can successfully intermediate. Assume with respect to the illiquid project that $i_0 = 1$, $a_2 = 1$ and $c_2 = 7/8$, and that, if the illiquid project is liquidated at date 1, 60 percent of their value is recovered: $a_1 = 1\frac{1}{8}$. Notice that IPH's "wealth endowment" is $a_1 - i_0 = 1/8$, i.e. an amount smaller than 1/4, the endowment of the wealthiest investor.

IPH considers two options, namely undertaking the illiquid project only issuing short-term debt to undertake both projects. When undertaking only the illiquid project IPH successfully manages to issue long-term debt $\langle 1, 0, 1 \rangle$ to reap the entire surplus of the illiquid project of 7/8. Now let us consider bank finance. From Program BF get that the solution satisfies $e^B = 1$, $L_0^B = 9/4$ and $D_1^B = 9/4$. Thus, in equilibrium the following happens. IPH first offers $k = \langle i_0 + I_0, D_1, 0 \rangle = \langle 9/4, 9/4, 0 \rangle$ and $\mathrm{I^N}$ just accepts. In stage 3 IPH exerts effort $e = 1$. The risky project turns into a success for sure because $Q(1) = 1$. At date 1 IPH successfully proposes to replace k by $k^S = \langle 9/4, 0, 9/4 \rangle$. At date 2 IPH repays $\mathrm{I^N}$ and keeps the remainder of the returns of the illiquid project and risky project. Her payoff becomes $1\frac{7}{8} + \frac{5}{2} - \frac{9}{4} = \frac{17}{8}$ and this exceeds the payoff when only undertaking the project. IPH chooses to be a bank in equilibrium and she outperforms the open capital market.

In this example the debt claim $k = \langle 9/4, 9/4, 0\rangle$ becomes risk-free, and it is successfully substituted at date 1 by $k^S = \langle 9/4, 0, 9/4\rangle$ at date 1. However, issuing a long-term debt contract $k = \langle 9/4, 0, 9/4\rangle$ ex ante would not work. Figure 5 (a) makes clear that in this case IPH would choose effort so as to maximize $Q(e)(a_2 + A_2 - D_2) - e = Q(e)5/4 - e$ and this would give $e < 1$. Therefore $k = \langle 9/4, 0, 9/4\rangle$ would not be risk-free and I^{N} would reject the contract at date 0. By the way, it is easily shown that IPH *cannot* issue any long-term debt contract to undertake both projects at all. IPH really has to set up as a fragile bank.

3 The liquidity risk of banks

3.1 Illiquid assets

The illiquid asset in the model has two relevant properties. First, it has a *low liquidation value*, i.e. when the illiquid asset is separated from the illiquid project holder it has a low market value. Second, the illiquid project has a *low debt capacity* compared to the future rents it generates. The theoretical literature has pointed out that these two characteristics often have a common source, namely substantial bargaining power of the manager of the illiquid project vis a vis the owners or financiers of the illiquid project.

The literature points to several reasons why a project can have a low debt capacity. First, more external finance would lead to adverse managerial incentives (see e.g. Jensen and Meckling (1976) or Myers (1977)). Examples of such adverse incentives in the context of banking are risk-shifting incentives or 'gambling for resurrection' (Flannery (1994)). A small variation is a situation in which investors have to incur costs when seizing the rents (see e.g. Townsend (1979) and Gale and Hellwig (1985)). Second, it can be that the rents are control rents, i.e. utility that the manager obtains when controlling the project (see e.g. Jensen (1986) or Aghion and Bolton (1989)). Third, the manager of the project may have information indicating that the rents of the project will be high, but cannot reveal this credibly to the market (Diamond (1991)). Fourth, the manager may not be able to commit her human capital to the firm (Hart and Moore (1994) or Diamond and Rajan (2001)). Finally, regulation can make it impossible to borrow up to the full extent of the surplus. In the context of banking this can be important because the Basle guidelines present a limit on the amount that can be borrowed (Bank for International Settlements, 2001). Notice that the Basle guidelines can be quite restrictive on the capacity to borrow because the book value of the bank's assets often underestimates the bank's market value.

Bank loans and reputational capital are two important bank assets that could correspond to the illiquid asset in my model. Bank loans have a low liquidation value because the bank manager has specific skills in the form of a relationship with the borrower (see e.g. Bhattacharya and Thakor (1993)). In addition there are informational problems that limit the liquidity of the loan portfolio. For example, if the bank's loan portfolio were entirely securitized potential buyers would fear buying bad loans ('lemons') from the bank. Banks can hence only securitize a small part of the loan portfolio in one go, or they must have built up a reputation to sell high quality assets. Bank loans also have a low debt value because of regulation and because a high level of debt leads to risk-shifting incentives.

Boot, Greenbaum and Thakor (1993) stress the importance of banks' investments in reputational capital. Reputational capital clearly is a long-term assets that has little value when separated from management. The debt capacity of reputational capital is typically also low because book keeping standards impose serious restrictions on the valuation of reputational capital and other intangibles. A high level of debt finance would thus leads to a negative book value of the bank's equity. Clearly legal environments as well as the

Basle norms forbid this.

3.2 Liquidity risk

Figure 7 and Figure 8 give an idea to what extent banks run a liquidity risk. The figures are based on 1997 balance sheet data of banks in the European Union (EU) and in the US and Canada (US/Can), respectively. The data was taken from *BankScope* of Bureau van Dijk Electronic Publishing. BankScope is a dataset with financial data of banks over the world and the coverage for the EU and US/Can is very good. In BankScope I selected 'large' Commercial Banks, Savings and Cooperative Banks, Real Estate & Mortgage Banks and Investment Banks & Security Houses.[11] This left me with 506 EU banks and 459 US/Can banks.

The 'illiquidity ratios' reported in Figure 7 and Figure 8 represent a rough measure of the amount of illiquid assets that are financed by liquid liabilities, i.e. deposits and other forms of short-term debt. In particular, the ratio of each bank is computed by taking the amount of liquid liabilities of the bank, subtracting the bank's liquid assets, and dividing the result by the bank's balance sheet total. The bank's liquid liabilities are obtained by adding up the BankScope variables 'money market funding' and 'total deposits'.[12] Its liquid assets are obtained by adding 'cash and due from banks' and 'total other earning assets'.[13] Thus, the illiquidity ratio represents the part of the bank's total assets that are illiquid and financed with liquid claims. And, all other things equal, a higher value of the ratio implies that the bank runs a higher liquidity risk. By construction, the illiquidity ratio is a number between minus one and one. It is minus one if the bank has only liquid assets and is entirely financed long-term. The ratio is one if the bank has only illiquid investments, but is entirely financed with liquid claims.

Figure 7 and Figure 8 give the number of banks that have similar illiquidity ratios in the year 1997.[14] For example, the number 42 at an illiquidity ratio of 0.5 in Figure 7 means that 42 EU banks have an illiquidity ratio between 0.45 and 0.50. The figures show that both EU banks and US/Can banks subject themselves to a serious liquidity risk. In 1997 only 69 of the 498 EU banks for which we have an observation, have an illiquidity ratio of less than 0.10. A typical bank in the EU has an illiquidity ratio between 0.30 and 0.60. In the US/Can the picture is even more pronounced: just 22 of the 459 banks have an illiquidity ratio of less than 0.10, and roughly half of the balance sheet consists of illiquid assets that are financed with liquid claims.

The evidence above has show that, first, the banking sector as a whole runs a serious liquidity risk and, second, almost all individual banks run a liquidity risk.

4 Discussion and Conclusion

In this paper I have presented a theory of the firms that explains why non-observable (opaque) activities are sometimes better undertaken by firms than individual agents. The theory shows that there synergies between opaque activities and illiquid assets, provided that the firm is financed with enough short-term hard claims. Managerial performance is boosted when the firm's assets become less liquid.

When the opaque activities take on the form of screening and monitoring investment projects the firm can be well be interpreted as a commercial bank. Indeed banks as screeners and monitors satisfy the main predictions of the model. They hold illiquid assets in the form of illiquid loans and reputational capital, and they depend to a large extent on hard financial claims such as deposits.

The theory potentially has important policy consequences. One prediction is that banks exist precisely *because* of their fragile financial structure. Taking away the bank's liquidity risk would undermine the market for monitoring services. Hence, according to the theory 'narrow banking' proposals, which prescribe that banks match the maturity structures of their assets and liabilities, are harmful.

The theory possibly also helps answering an interesting open question: Why do banks often hold the loans they originate on the balance sheet? Alternatively, banks could securitize their complete portfolio of illiquid loans. The theory argues that full securitization is not efficient absent other illiquid assets. The loan portfolio has an as of yet undetected function, namely to stimulate bankers to exert effort. Yet, the theory also shows that a banks reputational capital may serve the same function. Therefore, banks with a valuable reputation or brand name can have plenty of scope to securitize the loan portfolio.

Venture capital funds seem to form a counter example of the model. Indeed, venture capital funds exert substantial effort in monitoring 'small firms', but they are typically financed with *long-term* capital. A possible reason for this may be that the surplus that is involved is big enough to adopt high-powered (and expensive) incentives schemes such as option plans. Also venture capital funds often seem to have one, or a few, big shareholders who actively monitor the funds' management. In defense of the theory, managers of venture capital funds often do hold illiquid assets. First, the shares they hold in firms are often subject to lock-up arrangements. Such arrangements are an artificial way to make these shares perfectly illiquid for a period of time. Also, reputational capital seems of great importance for venture capitalists.

An important caveat of the theory is that it applies only to entrepreneurial firms. It is assumed that the illiquid project holder, who controls the bank, is also the residual claimant. However, in reality we see that banks are often publicly-held firms. When ownership and control are separated, the model only makes sense if the incentives of the bank managers are for some reason sufficiently in line with the owners' objectives. However, Jensen (1986) argues that this is often not the case for firms more generally. Let us argue in the spirit of the model what could be a possible resolution to this criticism. The model shows that the incentives of the bank manager and its financiers are better alined if the bank manager reaps a part of the illiquid project's rents, namely c_2. However, is it realistic to assume that bank managers reap a substantial part of the bank's loan portfolio or its reputational capital? The assumption seems only to be validated when bankers own substantial fractions of shares. The situation changes if bankers enjoy running the bank so that the rents c_2 represent *control rents*. Indeed, Jensen's argument was based on the assumption that managers obtain a stream of private benefits when retaining control. It may also be that the incentives of the owners and managers are simply sufficiently aligned in reality, so that the model applies to the agency problem between shareholders and fixed claim holders. However, in this case the theory would actually predict that banks are best wholly financed with equity claims!

A Proofs

A.1 Proof of Proposition 1

We prove the statements in a convenient order.

Statement (iii) If there is a solution we have $e^M > \underline{e}$ because otherwise $Q(e^M) = 0$, so that restriction 8 would be violated. Now show that $e^M < e^{FB}$ in case $e^M < \overline{e}$. From $\underline{e} < e^M < \overline{e}$ and equation 6 we get that e^M is given by

$$Q'(e^M)(A_2 - D_2^M) - 1 = 0 \tag{18}$$

From restriction 7 we obtain $D_2^M > 0$. Equation 18 with $D_2^M > 0$ implies that $e^M < \widetilde{e}$, where $\widetilde{e}$ is defined by $Q'(\widetilde{e})A_2 - 1 = 0$. We have obtained $e^M < \min\{\overline{e}, \widetilde{e}) = e^{FB}$.

Statement (i). First, if there is a solution to Program OMF it satisfies

$$Q(e^M)D_2^M - L_0^M = 0 \tag{19}$$

[If this were not the case, L_0 could be slightly increased to increase the maximand, while remaining in the feasible region.] When using 19, the objective function simplifies to $Q(e)A_2 - e - I_0$. As $e^M < e^{FB}$ we see from this equation that the value of the objective increases in e near the optimum. We are thus looking for the maximum e such that all restrictions are satisfied. Equation 18 shows that this is equivalent to looking for the smallest possible value of D_2. As we look for the smallest possible D_2 we must have that restriction 5 binds in the optimum ('no over-borrowing').

$$\text{s.t } L_0^M = (1 - f)I_0 \tag{20}$$

Solutions to Program OMF satisfy equations 18—20. As for uniqueness, assume (e^0, L_0^0, D_2^0) and (e^1, L_0^1, D_2^1) are two optima. Equation 20 shows that $L_0^0 = L_0^1$. We must also have $e^0 = e^1$ because the maximand increases in e over the relevant interval. Equation 18 shows that $e^0 = e^1$ implies $D_2^0 = D_2^1$.

Statement (iv). By the Implicit Function Theorem. The signs of the derivatives can be determined for instance by looking at the Kuhn-Tucker optimality conditions of Program OMF. We can also get the signs more directly: Suppose, a small change $\Delta f > 0$ leads to changes Δe^M and ΔD_2^M. Equation 18 shows that either $\Delta e^M > 0$ and $\Delta D_2^M < 0$ or $\Delta e^M < 0$ and $\Delta D_2^M > 0$. However, $\Delta e^M < 0$ and $\Delta D_2^M > 0$ is impossible because $\Delta f > 0$ enlarges the feasible set of Program OMF so that the value of the objective cannot decrease (recall that the objective is increasing in e in the relevant interval).

Statement (ii). This follows directly from statement (iv) ($\underline{f} < 1$ because else the solution would be the first-best solution).

A.2 Proof of Lemma 2

First solve the subgame with long-term finance, i.e. the subgame described in Figure 5 (a). The proof follows by applying Proposition 1 (iv) to the solution.

Use backward induction to derive the solution. In stage 3 IPH chooses effort so as to maximize expected payoff $e \in \arg\max_{\widetilde{e}} \{Q(\widetilde{e})(a_2 + A_2 - D_2) - \widetilde{e}\}$. In stage 2 $\mathrm{I^N}$ accepts the contract if and only if $Q(e)D_2 + (1 - Q(e))a_2 \geq i_0 + I_0$. In stage 1 IPH offers k so as to maximize $Q(e)(a_2 + A_2 - D_2) + c_2 - e$. IPH's individual rationality constraint is $Q(e)(a_2 + A_2 - D_2) + c_2 - e \geq S^{\text{Illiquid Project}}$, where $S^{\text{Illiquid Project}}$ is the surplus of the illiquid project only (see Lemma 2 in the text)

Now define $D_2' \equiv D_2 - a_2$, $L_0 = i_0 + I_0 - a_2$, and $f^{IPH} = \frac{a_2 - i_0}{I_0}$, and substitute these into the equations above. We obtain that the equilibrium solves

$$\max_{e, L_0, D_2} Q(e)(A_2 - D_2') + c_2 - e$$

$$\text{s.t } L_0 = (1 - f^{IPH})I_0$$

$$e \in \arg\max_{\widetilde{e}} \{Q(\widetilde{e})(A_2 - D_2') - \widetilde{e}\}$$

$$Q(e)D_2' - L_0 \geq 0$$

$$Q(e)(A_2 - D_2') - e \geq S^{\text{Illiquid Project}} - c_2$$

Notice the intimate relationship with Program OMF of the main text. In particular, it can be easily shown that if the programming problem has a solution, say (e^L, L_0^L, D_2^L), then it is the same as the generic solution for Program OMF.

We can thus apply the results of Proposition 1 directly to (e^L, L_0^L, D_2^L). Proposition 1 (iv) states that if there is a solution we must have $e^L < e^M$. This is because the wealthiest investor has an endowment of $\overline{f}I_0$, where $\overline{f} > \frac{a_2 - i_0}{I_0} = f^{IPH}$ (See equations 10 and 11.)

A.3 Proof of Lemma 3

The statements in the lemma are proved by first solving the subgame of Figure 5 (b).

Use backward induction, starting at date 1. First, assume that nature has decided the risky project will fail. Notice that k_1^f satisfies $D_2^f \leq a_2$, so that $D_2^f - i_0 + I_0 < a_1 - i_0 + I_0$. Hence, in equilibrium $\mathrm{I^N}$ liquidates IPH's assets. Conclusion: the equilibrium payoffs are $(a_1 - L_0, -e)$ in case of a failure.

Now assume that the risky project will be a success. In equilibrium $\mathrm{I^N}$ accepts k_1^s if and only if $D_2^s \geq D_1$. Thus, one stage earlier, IPH chooses k_1^s such that $D_2^s = D_1$ if that is feasible, i.e. iff $D_1 \leq a_2 + A_2$. In this case the equilibrium payoffs are $(a_2 + c_2 + A_2 - D_1 - e, D_1 - L_0)$. If, instead, $D_1 > a_2 + A_2$ so that $\mathrm{I^N}$ rejects any k_1^s, the equilibrium payoffs are $(a_1 + A_2 - D_1 - e, D_1 - L_0)$.

Now turn to the last stage at date 0. If $D_1 \leq a_2 + A_2$, IPH chooses effort as follows[15]

$$e \in \arg\max_{\widetilde{e}} \{Q(\widetilde{e})(a_2 + c_2 + A_2 - D_1) - \widetilde{e}\}$$

In stage 2, $\mathrm{I^N}$ accepts k if her expected payoffs exceed the investment amount $L_0 = i_0 + I_0$

$$Q(e)D_1 + (1 - Q(e))a_1 - L_0 \geq 0$$

In stage 1 IPH offers k so as to maximize her expected payoff. If $D_1 \leq a_2 + A_2$, her payoff becomes[16]

$$Q(e)(a_2 + c_2 + A_2 - D_1) - e$$

However, IPH also requires that she is at least as well off as only undertaking the illiquid project. In other words, if $D_1 \leq a_2 + A_2$ we have[17]

$$Q(e)(a_2 + c_2 + A_2 - D_1) - e \geq S^{\text{Illiquid Project}}$$

The equations above show that if Program BF has a feasible solution then IPH would like to issue $k = \langle i_0 + I_0, D_1, 0 \rangle$ to undertake both projects.

Complete the proof by showing the IPH would like to issue $k = \langle i_0 + I_0, D_1, 0 \rangle$ to undertake both projects *only if* Program BF has a solution. In theory, there are two alternatives for IPH, namely long-term finance and issuing a contract k for which $D_1 > a_2 + A_2$. Lemma 2 shows that long-term finance is not an option. Verify that if $D_1 > a_2 + A_2$ IPH does not outperform the open capital market by studying the relevant programming program (see the footnotes above). Substitute $D_2' \equiv D_2 - a_1$ and $f^{IPH} = \frac{a_1 - i_0}{I_0}$ to see that it has the same generic solution as Program OMF of the main text. However, equation 11 shows that the wealthiest investor has an endowment of $\overline{f} I_0$, where $\overline{f} > \frac{a_1 - i_0}{I_0} = f^{IPH}$. Hence, proposition 1 (iv) states that IPH does not outperform the open capital market.

A.4 Proof of Proposition 3

Statement (i). The participation constraint (i.e. the fourth restriction) binds in the optimum, i.e. $Q(e)(D_1 - a_1) + a_1 - L_0 = 0$. The third restriction of Program BF gives the effort choice. Effort is either given by $e = \overline{e}$, or by $Q'(e)(a_2 + c_2 + A_2 - D_1) - 1 = 0$.

Statements (ii) and (iii) are all directly derived from analyzing the two equations above and $L_0 = i_0 + I_0$. Let me proof statement (ii) as a example. From the two equations above and $L_0 = i_0 + I_0$ we obtain

$$\begin{pmatrix} Q''(e)(a_2 + c_2 + A_2 - D_1) & -Q'(e) \\ Q'(e)(D_1 - a_1) & Q(e) \end{pmatrix} \begin{pmatrix} \frac{de^B}{d(a_2+c_2)} \\ \frac{dD_2^B}{d(a_2+c_2)} \end{pmatrix} = \begin{pmatrix} -Q'(e) \\ 0 \end{pmatrix}$$

Solving the system delivers statement (ii) (By the way, optimality implies that the determinant of the matrix above is negative near the optimum).

References

Aghion, P. and P. Bolton, 1989, The Financial Structure of the Firm and the Problem of Control, *European Economic Review* 33, 286-293.

Aghion, P. and P. Bolton, 1992, An Incomplete Contracting Approach to Financial Contracting, *Review of Economic Studies* 59, 473-494.

Bank for International Settlements, 2001, Overview of the New Basel Capital Accord, Basel Committee on Banking Supervision, Bank for International Settlements, January 2001.

Berglöf, E. and E-L.Von Thadden, 1994, Short-term versus Long-term Interests: Capital Structure with Multiple Investors, *Quarterly Journal of Economics* 109, 1055-1084.

Bhattacharya, S. and A.V. Thakor, 1993, Contemporary Banking Theory, *Journal of Financial Intermediation* 3, 2-50.

Boot, A.W.A., S.I. Greenbaum and A.V. Thakor, 1993, Reputation and Discretion in Financial Contracting, *American Economic Review* 83, 1165-1183.

Calomiris, C.W. and C.M. Kahn, 1991, The Role of Demandable debt in Structuring Optimal Banking Arrangements, *American Economic Review* 81, 497-513.

Campbell, T.S. and W.A. Kracaw, 1980, Information Production, Market Signalling, and the Theory of Financial Intermediation, *Journal of Finance* 35, 863-882.

Diamond, D.W., 1984, Financial Intermediation and Delegated Monitoring, *Review of Economic Studies* 51, 393-414.

Diamond, D.W., 1991, Debt Maturity Structure and Liquidity Risk, *Quarterly Journal of Economics* 106, 709-737.

Diamond, D.W. and P.H. Dybvig, 1983, Bank Runs, Deposit Insurance, and Liquidity, *Journal of Political Economy* 91, 401-419.

Diamond, D.W. and R.G. Rajan, 2001, Liquidity Risk, Liquidity Creation, and Financial Fragility: A Theory of Banking, Journal of Political Economy 109, 287-327.

Flannery, M.J., 1994, Debt Maturity and the Deadweight Cost of Leverage: Optimally Financing Banking Firms, *American Economic Review* 84, 320-331.

Gale, D. and M. Hellwig, 1985, Incentive-Compatible Debt Contracts I: The One Period Problem, *Review of Economic Studies* 52, 647-664.

Hart, O., 1995, *Firms, Contracts, and Financial Structure*, Clarendon Press, Oxford University Press Inc., New York.

Hart, O. and J. Moore, 1988, Incomplete Contracts and Renegotiation, *Econometrica* 56, 755-785.

Hart, O. and J. Moore, 1994, A Theory of Debt Based on the Inalienability of Human Capital, *Quarterly Journal of Economics* 109, 841-880.

Hart, O. and J. Moore, 1995, Debt and Seniority: An Analysis of the Role of Hard Claims in Constraining Management, *American Economic Review* 85, 567-585.

Jensen, M., 1986, Agency Costs of Free Cash Flow, Corporate Finance and Takeovers *American Economic Review, Papers and Proceedings* 76-2, 323-329.

Jensen, M. and W. Meckling, 1976, Theory of the Firm: Managerial Behavior, Agency Costs and Capital Structure *Journal of Financial Economics* 3, 305-360.

Leland, H.E. and D.H. Pyle, 1977, Informational Asymmetries, Financial Structure, and Financial Intermediation, *Journal of Finance* 32, 371-387.

Morgan, D.P., 2000, Rating Banks: Risk and Uncertainty in an Opaque Industry, *Staff Report FRBNY*, No. 105.

Myers, S.C., 1977, Determinants of Corporate Borrowing, *Journal of Financial Economics* 5, 147-175.

Myers, S.C. and R.G. Rajan, 1998, The Paradox of Liquidity, *Quarterly Journal of Economics* 119, 733-771.

Qi, J., 1997, Deposit Liquidity and Bank Monitoring, *Journal of Financial Intermediation* 7, 198-218.

Townsend, R.M., 1979, Optimal Contracts and Competitive Markets with Costly State Verification, *Journal of Economic Theory* 21, 265-293.

Winton, A., 1995, Costly State Verification and Multiple Investors: The Role of Seniority, *Review of Financial Studies* 8, 91-123.

Footnotes:

[1]Illiquidity of the illiquid project is conveniently modeled in an incomplete contracting framework.

[2]Punishment in retrospect could be difficult, for example because of lack of hard evidence, or because the legal environment forbids certain forms of punishment, or because of limited liability restrictions.

[3]In Diamond and Rajan (2001) illiquid assets serve no function. They are kept on the balance sheet of a deposit taking institution because the deposit contract brings in a coordination problem between the depositors. This coordination problem reduces the banker's power to renegotiate the deposit contract. Deposit claims are liquid precisely because they are not renegotiable. Thus, banks transform illiquid loans into liquid deposits.

[4]This discussion shows that this paper and the work of Calomiris and Kahn (1991), Qi (1997) and Diamond and Rajan (2001) lead to a different empirical prediction as to the timing of a bankrun. In the latter papers the bankrun is triggered by mismanagement. In my paper runs also occur after a bad signal with respect to the bank's risky project, or when the illiquid project disappears.

[5]Full duplication of monitoring is an extreme assumption, but it is merely made for simplicity and could be relaxed. However, I do need to assume that the total monitoring cost increases in the number of monitoring investors. This would be true if investors face costs to coordinate their efforts (e.g. 'voting costs').

[6]In principle, D_1 could be greater than zero, because I^{M} could repay D_1 by issuing a new contract at date 1. However, because I^{M} has no wealth of her own at date 1, and she takes no decisions at date 1, we can assume without loss of generality that $D_1 = 0$.

[7]For early work on incomplete contracts in finance, see e.g. Hart and Moore (1988) or Aghion and Bolton (1992). Two of many papers that implement the theory by distinguish-

ing project returns in 'assets' and 'cash' are Berglöf and Von Thadden (1994) and Hart and Moore (1995). Notice that the empirical counterpart of 'cash' need not necessarily be the illiquid project's cash-flows. In the same vein 'assets' need not be the physical assets of the illiquid project. Nevertheless, these interpretations can be appropriate in a situation in IPH can divert the cash-flows of the illiquid project. For example, think of a situation in which IPH can invest the cash flows in some negative net present value project that is not modeled (Jensen, 1986).

[8]IPH could also undertake the risky project and leave the illiquid project untouched. However, this option not interesting as IPH has no fund endowment. Proposition 1 shows that a wealthy investor in the market would be a better monitor than IPH.

[9]In principle, it would be possible to condition the short-term debt contract on the outcome of the signal. It can be shown, however, that this would not affect the outcome of the model. In particular, it can be shown that for the bank to outperform the open capital market it *must* be that the date-1 repayment requirement for a bad signal exceeds the amount the bank can credibly pay back at date 2. Hence, in case of a bad signal depositors liquidate the bank which also results from the present model.

[10]We can assume here that $\min\{D_2, a_2\} = a_2$ because I^{N} has accepted the contract at date 0. This can only be the case if $D_2 \geq i_0 + I_0$, and we know from equation 11 that $i_0 + I_0 > a_2$.

[11]The selected banks were also 'living banks' with reports in 'raw data format' and consolidation codes C1, C2, C* and U1. I downloaded the balance sheets for the years 1993-1998.

[12]Money market funding: e.g. certificates of deposit, commercial paper and debt securities.

[13]Total other earning assets: e.g. deposits with banks, due from central banks, due to other banks, total securities, T-bills, bonds, certificates of deposit, equity investments and

other investments.

[14]The figures only give 1997 data. I also computed the statistics for 1993-1996 and 1998 but they results all looked very similar. I picked the year 1997 as in 1998 many observations were missing. I have also computed an illiquidity ratio for which it was assumed that in every year a fifth of the long-term assets and liabilities mature. Again, it is not shown because the pattern was very similar the pattern observed in the figures. Finally, I tried to compute a similar ratio that expresses the amount of non-demandable assets which is financed by demandable debt. This attempt failed, however, due to lack of appropriate data.

[15]And, if $D_1 > a_2 + A_2$ IPH chooses $e \in \arg\max_{\widetilde{e}}\{Q(\widetilde{e})(a_1 + A_2 - D_1) - \widetilde{e}\}$.

[16]And, if $D_1 > a_2 + A_2$ IPH's expected payoff becomes $Q(e)(a_1 + A_2 - D_1) - e$.

[17]And, if $D_1 > a_2 + A_2$ IPH requires $Q(e)(a_1 + A_2 - D_1) - e \geq S^{\text{Illiquid Project}}$.

Figure captions:

Figure 1: The risky project

Figure 2: The financing game in case of open market finance of the risky project.

Figure 3: The illiquid project

Figure 4: The renegotiation game at date 2

Figure 5: The financing game when IPH undertakes both projects

Figure 5a: Long-term debt

Figure 5b: Bank finance

Figure 6: Open Market Finance versus Bank Finance

Figure 7: The illiquidity ratio for EU banks in 1997

Figure 8: The illiquidity ratio for banks in the US and Canada in 1997

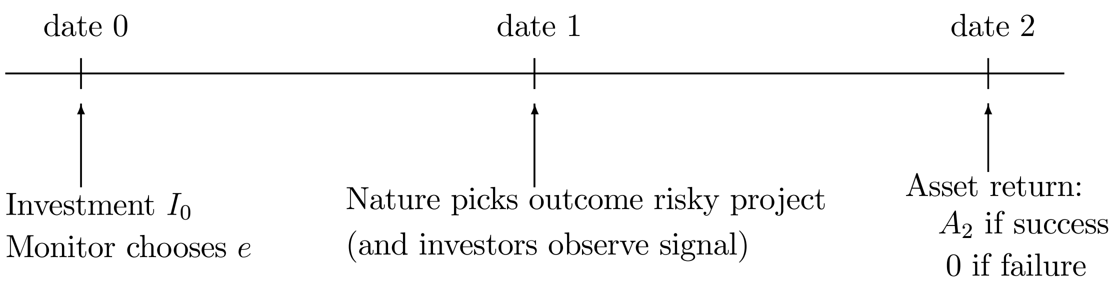


Figure 1: The risky project

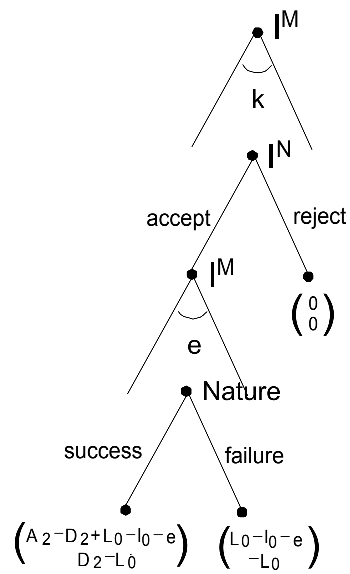


Figure 2: The financing game in case of open market finance of the risky project.

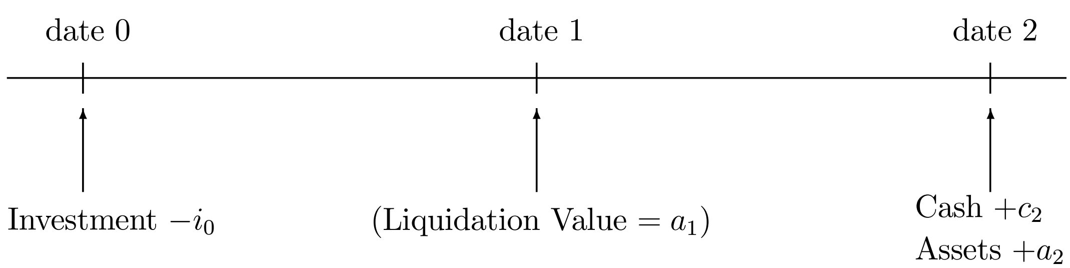


Figure 3: The illiquid project

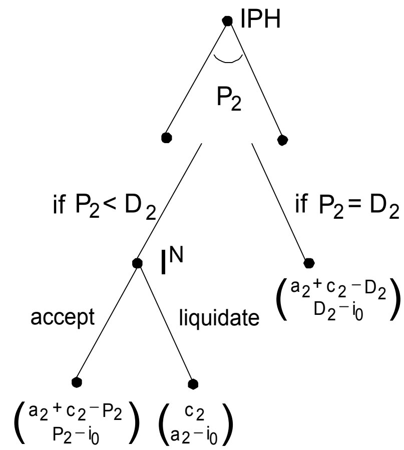
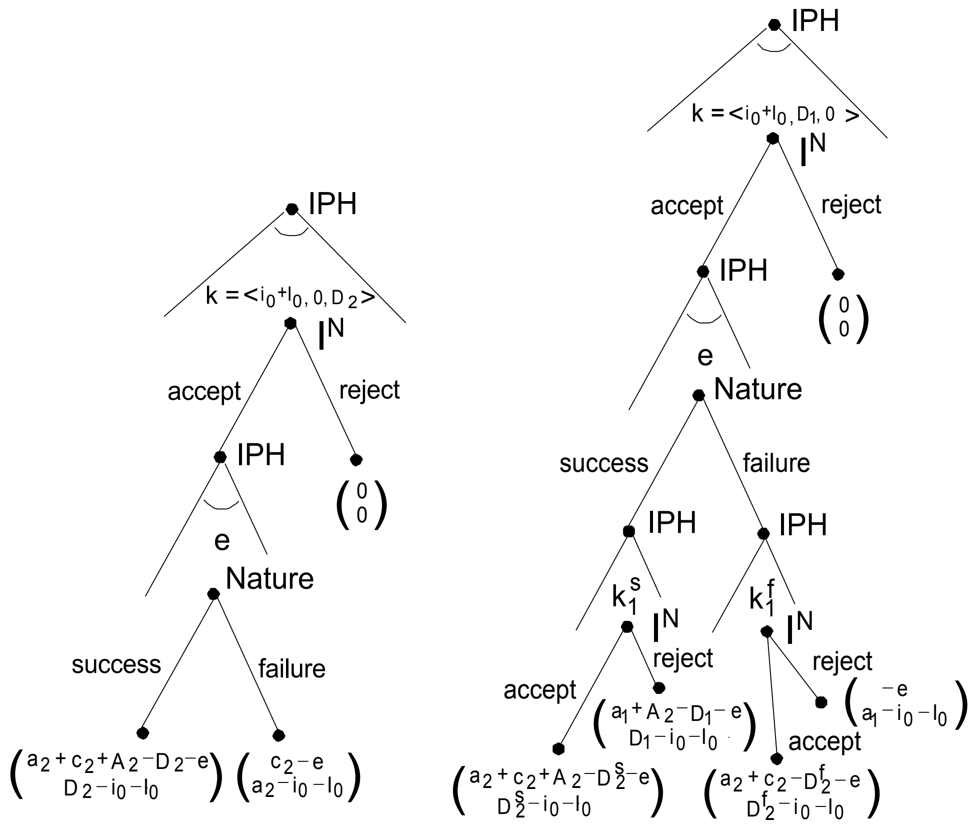


Figure 4: The renegotiation game at date 2



(a) Long-term debt

(b) Bank finance

Figure 5: The financing game when IPH undertakes both projects

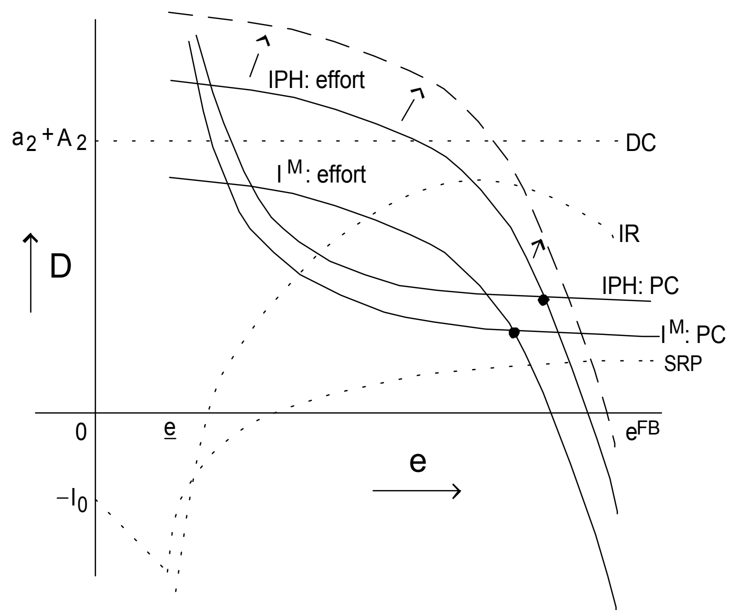


Figure 6: Open Market Finance versus Bank Finance

Illiquidity ratio	# Banks
-0.5	1
-0.45	0
-0.4	0
-0.35	0
-0.3	0
-0.25	5
-0.2	2
-0.15	2
-0.1	3
-0.05	6
0	16
0.05	18
0.1	16
0.15	17
0.2	15
0.25	20
0.3	32
0.35	40
0.4	53
0.45	44
0.5	42
0.55	34
0.6	30
0.65	23
0.7	30
0.75	28
0.8	11
0.85	5
0.9	1
0.95	4
1	0
Number of Banks	506
Missing Observations	8

Figure 7: The illiquidity ratio for EU banks in 1997

Illiquidity ratio	# Banks
-0.5	0
-0.45	0
-0.4	0
-0.35	0
-0.3	1
-0.25	1
-0.2	1
-0.15	3
-0.1	1
-0.05	4
0	4
0.05	1
0.1	6
0.15	6
0.2	4
0.25	8
0.3	26
0.35	28
0.4	60
0.45	58
0.5	94
0.55	81
0.6	39
0.65	20
0.7	10
0.75	3
0.8	0
0.85	0
0.9	0
0.95	0
1	0
Number of Banks	459
Missing Observations	0

Figure 8: The illiquidity ratio for banks in the US and Canada in 1997